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TEN YEARS OF SCIENCE AT UNESCO

by

MARCEL FLORKIN

Marcel Florkin, Professor of Biochemistry at Liège University and President of the International Union of Biochemistry, has been a member of the Belgian delegation to each of the eight sessions of Unesco's General Conference. He is the author of over four hundred papers on comparative biochemistry and the history of science and of several books including: Introduction à la biochimie générale, *1943;* Précis de biochimie humaine, *1943;* L'évolution biochimique, *1944 (translations published in the Union of Soviet Socialist Republics, the United States of America*[1] *and Italy);* Aspects biochimiques communs aux êtres vivants, *1956.*

In the middle of the second world war, at the end of 1942, Mr. R. A. Butler, then United Kingdom Minister of Education, took the initiative of bringing together in London his colleagues of the allied nations for conversations on certain matters of common interest. Several such meetings were subsequently held, and from them emerged the idea of a 'United Nations Educational and Cultural Organization'. After the allied victory, a committee was set up to study the implementation of this project, and a preparatory conference was convened in London in November 1945. The constitution proposed by this conference on 16 November 1945 was that of a 'United Nations Educational, Scientific and Cultural Organization'—i.e. Unesco.

THE 'S' IN UNESCO

By inserting into what was originally to have been 'Uneco' the 's' which converted it into Unesco, the London preparatory conference was deciding to include the sciences in a world scheme of intellectual co-operation. The International Institute for Intellectual Co-operation, established by the League of Nations, had already, it is true, made laudable efforts in the realm of science; but the fundamental difference between the Institute, which was an assemblage of distinguished individuals, and Unesco, which is an association of States, must constantly be borne in mind. Unesco as we know it today is defined in two sentences occurring in resolutions adopted by the eighth session of the General Conference (Montevideo, 12 November to 11 December

1. English title: *Biochemical Evolution,* 1949.

1954): 'Universality is the basic principle and *raison d'être* of Unesco. The purpose of Unesco is to promote collaboration among the nations through education, science and culture.'

In the field with which we are concerned, the policy defined at Montevideo allots to Unesco the task of developing scientific co-operation between the nations. It also lays down the principle of government representation on the Organization's three governing bodies:

1. The General Conference, which, ever since the inception of Unesco, has consisted of plenipotentiaries of the Member States.
2. The Executive Board, elected by the General Conference, under whose authority it acts and to which it is responsible. From the first General Conference (1946) to the end of the eighth (1954), the Executive Board was a corporation of individuals, appointed by the General Conference to carry out, in the intervals between plenary sessions, the decisions reached at those sessions. Since the end of the eighth General Conference, the Executive Board has become a corporation of 22 representatives of States, exercising on behalf of the whole conference the powers delegated to them.
3. The Secretariat, consisting of the necessary staff and headed by the Director-General of the Organization. The Director-General is nominated by the Executive Board and appointed by the General Conference.

Unesco is therefore a 'co-operative society' of States, formed to promote collaboration among nations through education, science and culture. The present definition is the outcome of confronting the views of the Secretariat with those of the Executive Board, and then of confronting the result thus obtained with the views of the General Conference. These successive confrontations have, in the course of the last ten years, given substance to the idea of international scientific co-operation. The writings of Father Mersenne contain the first definition of this concept, together with that of the underlying unity of the sciences and the collective nature of scientific work. 'The sciences', he wrote in a fine passage in his *Préludes de l'harmonie universelle* (1634), 'have sworn to an inviolable fellowship, and it is all but impossible to separate them, for they suffer when they are torn apart.' He even proposed the foundation of an international academy, its universality to be guaranteed by the patronage of the Pope and Princes. But the times, 'hardened against everything but luxury, folly and ungodliness', took little heed of learning. The great ones of the earth were blind to their duty of fostering research. And yet, asked the worthy Father in his *Vérité des Sciences,* how can the deviation of the magnetic needle at the various points of the earth's surface be ascertained without assembling the results of observations made at those points?

The first attempts to build up a real international scientific organization took the form of various international congresses convened between 1870 and 1900, though the desire for international scientific collaboration had

found expression from time to time as far back as the beginning of the nineteenth century. The year 1824 saw the first steps for the preparation of an international map of the heavens. In 1898, an International Association of Academies began slowly to get under way, but failed to have any practical effect until after the first world war when, rechristened the International Research Council (IRC), it took as its aim the establishment of an international union in every branch of science. These unions met with varying fortunes, ranging from success in the realm of astronomy to temporary failure in that of mathematics. In 1931 the IRC became the ICSU—International Council of Scientific Unions—with the task of co-ordinating the activities of those unions. Working with very limited funds, ICSU managed to meet its secretariat expenses and to publish a few reports. After the interruption due to the second world war, the unions resumed their activity in 1945, and their importance became manifest. To continue its task of co-ordinating and guiding them, ICSU needed more funds. Subscriptions from member countries were therefore multiplied by five. This step had certain drawbacks; for while the State contributions had originally represented two-thirds of ICSU's income, after this change they amounted to six-sevenths. The resultant situation, in which the unions within the Council are relegated to a position inferior to that of the States, is bound to cause some misgiving.

When the final act for the establishment of Unesco was signed in London on 16 November 1945, it was decided that a preparatory committee should organize the first General Conference and set up a secretariat to assemble information and make proposals. At the first session of the General Conference, which opened in Paris on 19 November 1946, the first dialogue took place between the Director of the Secretariat's Science Section—Joseph Needham, the distinguished biochemist and scientific historian—and a Sub-Commission on Natural Sciences, set up by the General Conference. The Chairman of this Sub-Commission was H. J. Bhabha (India), and its Vice-Chairman the late Miguel Ozorio de Almeida (Brazil). The Rapporteur was Pierre Auger (France), who in 1948 succeeded Joseph Needham as the head of Unesco's Department of Natural Sciences. He had the help of three Deputy Rapporteurs—W. A. Noyes (United States), A. H. Compton (United States) and the present writer (Belgium).

The report submitted by the Secretariat emphasized that the primary task of the Department of Natural Sciences was to work for international co-operation in the scientific field. It summed up in six propositions the permanent aims to be pursued by Unesco in that respect:

1. to establish a world-wide network of field science co-operation offices;
2. to support the scientific unions, add to their number and assist them in their work;
3. to organize and operate an international clearing house for scientific information;

4. to support the work of the United Nations and its specialized services;
5. to inform the general public in all countries of the international implications of scientific discoveries;
6. to create new forms of international scientific co-operation (international observatories and laboratories, etc.).

In the light of these principles, the Sub-Committee laid down the lines on which the Secretariat was to work during 1947 in a programme the chief chapters of which dealt with co-operation with international scientific unions, the creation of science co-operation offices, the improvement of scientific documentation and abstracting, the popularization of the natural sciences, and the establishment of an International Institute of the Hylean Amazon —the first of Unesco's own experiments in international scientific collaboration and one which, it must be admitted, ended in utter failure.

UNESCO'S DOCTRINE IN THE FIELD OF INTERNATIONAL SCIENTIFIC CO-OPERATION

The second session of the General Conference (Mexico, 1947) confirmed the first directives; it decided to continue the activity of the field science co-operation offices, the preparatory work for the establishment of the Institute of the Hylean Amazon, and co-operation with international scientific unions. Advancing further along the path of international scientific collaboration, the programme for 1948 made provision for a conference of experts to advise on the best methods of assisting scientific progress in Latin America. This conference met at Montevideo in September 1948. Other conferences of experts were convened to study the establishment and maintenance of high altitude stations—the conference on this subject met at Interlaken—and cartographic services.

In 1948, Unesco collaborated with the World Health Organization (WHO) in laying the foundations of a permanent Council for the Co-ordination of International Congresses of Medical Sciences.

In the programme adopted by the third session of the General Conference (Beirut, 1948) the same basic topics reappear—co-operation with scientific organizations, and field science co-operation offices. Taking for granted the establishment of the Institute of the Hylean Amazon, the General Conference embarked upon further co-operative enterprises—studies with a view to the creation of an International Institute of the Arid Zone and of an International Computation Centre. It called for fresh efforts to set up a permanent bureau for the co-ordination of International Congresses of Medical Sciences and bring about international organization in the technological sphere.

To sum up, during the period 1946 to 1948, when Julian Huxley was Director-General, the Department of Natural Sciences laid the accent quite

definitely on a programme of international scientific co-operation, the three basic features of which continued to be support for the scientific unions and the Council in which they are federated, the development of field science co-operation offices, and the initiation of new forms of scientific co-operation (international institutes, etc.). The numerous other items brought forward in the enthusiastic atmosphere of the first session were gradually relegated under the heading World Centre of Scientific Liaison (exchange of scientists, provision of travel facilities, exchange of information on scientific films, standardization of abstracts, preparation of a world register of scientists, standardization of scientific publications, etc.). These activities, always intermittent, underwent a gradual decline.

Jaime Torres Bodet having succeeded Julian Huxley as Director-General, the fourth session of the General Conference (Paris, 1949) selected from the long-term programme drawn up at Beirut a number of items to receive priority in 1950. As regards the natural sciences, these items were aid to international scientific associations, strengthening of the field science co-operation offices, and surveys for the ultimate foundation of an International Institute of the Arid Zone. The fifth session of the General Conference (Florence, 1950) was strongly influenced by the views of the new Director-General. Of the 10 items in the general programme drawn up at Florence, the first dealt with the elimination of illiteracy and only one related to the natural sciences. This declared that one of Unesco's chief tasks was 'to promote the progress and application of science for the benefit of mankind'. Thus we find generous and humane considerations superimposed upon scientific co-operation. Nevertheless, aid to international associations and field science co-operation offices still occupied the foreground in the Natural Sciences chapter of the 1951 programme. The latter also called for the creation of regional laboratories and research centres.

As early as 1946, the United Nations Economic and Social Council had striven to determine the points on which international co-operation should concentrate in order to increase man's mastery of nature by adding to his knowledge. In 1949 a committee of experts convened by Unesco indicated a number of criteria justifying the establishment of international institutions; the need for complicated and costly plant; the inevitably multi-territorial nature of projects; the fact that research of universal importance sometimes has to be carried out on the territory of a country unable to assume the material burden involved; and the urgent need for an exceptional and effective effort. The committee of experts established an order of priority which was the outcome of a compromise between the urgency of the scientific need and the efficiency factor. On 1 December 1950, a joint committee of representatives of the United Nations Specialized Agencies adopted a revised list of priorities as a basis for action by Unesco:

1. International Computation Centre;

2. International Institute of Research on the Brain;
3. International Institute of Social Sciences;
4. International Astronomical Laboratory;
5. International Institute for the Chemistry of Living Matter;
6. International Meteorological Institute;
7. International Institute for Arid Zone Research;
8. Fluid and Soil Mechanics Laboratory;
9. Erosion Laboratory;
10. Institute of the Humid Tropical Zone;
11. Institutes of Oceanography and Fisheries;
12. Research Laboratory on the Utilization of Solid Fuels;
13. Research Laboratory on the Utilization of Solar Energy;
14. Regional Laboratory for the Physics of High Energy Particles.

It will be observed that the committee of experts ceased to use exclusively the term 'United Nations laboratory', and employed others—institute, or centre. Meanwhile, the Florence session (1950), adopting the project with the lowest priority on the list, requested the Director-General to encourage the foundation of a laboratory for nuclear research which would centralize the hitherto isolated efforts of Western European scientists. It is true that, as already mentioned, the third session of the General Conference (Beirut, 1948) had given directions for preliminary studies on the establishment of the International Computation Centre, to which the committee of experts had assigned first priority having regard to the urgency of the need and the probability of success. The same session also displayed keen interest in arid zone research, which the experts had placed rather low on the list of priorities. And from the multifarious assignment of the World Centre of Scientific Liaison, the 1951 programme adopted at Florence also extracted—while subdividing and strengthening them—the activities relating to the dissemination of scientific method, discoveries, and applications, one of the targets proposed being the popularization of science by means of travelling scientific exhibitions.

The sixth session of the General Conference (Paris, 1951) noted the establishment in 1950 of the Advisory Committee on Arid Zone Research and the Union of International Engineering Associations. The natural sciences programme for 1952 covered four topics: development of international scientific co-operation (aid to the international unions, field science co-operation offices); contribution to research, particularly for the improvement of the living conditions of mankind (international laboratories, arid zone, etc.); dissemination of science; action in the service of human rights in the field of science (the object of this new activity, which has led to little result, was to make a technical and legal study of international conventions and national regulations concerning the protection of the rights of scentists and inventors).

At the seventh session of the General Conference (Paris, 1952), the new

trend in Unesco's policy outlined at the Florence session was formulated in more precise terms by a group of supporting States which pressed for the replacement of international scientific co-operation by a new social contract pledging the nations which belonged to the sphere of Western civilization to share the benefits of modern science with those which did not yet enjoy them. In his report to the Conference, the Director-General formulated the doctrine which links this new social contract with international collaboration between scientists. He pointed out that international co-operation between scientists must be the enduring basis for any effort by Unesco to make the present-day world a better and a happier place. This trend, which had the backing of the Arab, Asian and Latin-American States from which the request had come, was opposed by the Western States, with the exception of France. These, the 'have' countries, called for a return in scientific matters to the less ambitious target of international collaboration between scientists.

There are, however, trends that cannot be reversed; and after the resignation of Jaime Torres Bodet and the appointment of Luther Evans as Director-General, the eighth session of the General Conference (Montevideo, 1954) promoted direct aid to Member States to the first rank among its schemes in the scientific as well as other realms. True, the Montevideo session again declared that Unesco's task was to further international collaboration through education, science and culture, but it stated that in 'promoting collaboration among the nations through science', Unesco should take four points into account: creative scientific work; the practical use of the results of research; the integration of these into the intellectual heritage of mankind; and the need for making the achievements of science available for the benefit of humanity. As regards creative scientific work, Unesco's task is still the development of international scientific co-operation through aid to the international scientific organizations. The programme drawn up at Montevideo for 1955 and 1956 also includes special activities connected with the arid zone, the humid tropical zone, and oceanography. The field science co-operation offices at Montevideo, Cairo, New Delhi and Jakarta are maintained. Various activities are prescribed for the teaching and dissemination of science. Defining the subjects which it regarded as particularly important under the heading of 'special activities', the eighth session described the top priority topic in the scientific field as being 'scientific research for the improvement of living conditions'.

Side by side with this dialectical evolution of the concept of scientific co-operation, Unesco's Department of Natural Sciences has, during the 10 years of its existence, gained considerable practical experience under the leadership of its distinguished chiefs. *Solvitur ambulando* was the motto used in the document which marked the department's start in life—the report submitted by the Secretariat of the Sub-Commission on Natural Sciences at the first session of the General Conference. In the course of these 10 years, experience

has shown the wisdom of concentrating chiefly on a limited number of projects, and thus a great measure of success has unquestionably been achieved. Having studied the development of Unesco's doctrine with regard to international scientific collaboration, it is now necessary to retrace the story of those achievements in the chronological order of events.

AID TO INTERNATIONAL SCIENTIFIC ORGANIZATIONS

International Council of Scientific Unions

As we have already seen, the International Association of Academies, which held its first meeting in Paris in 1900, gave birth in 1918 to the International Research Council (IRC) to which the unions concerned with the different branches of science were later affiliated. During the Council's general assembly which met in Brussels in July 1919, several international unions were established—Astronomy, Geodesy and Geophysics, Chemistry, and Mathematics. Others were formed subsequently—the International Scientific-Radio Union in 1921, the International Union of Physics in 1922, and the International Geographical Union in 1923. No country was permitted by the Council to join any union unless it had first become a member of the Council. In 1931, the unions' desire to become self-governing resulted in the International Research Council being converted into the International Council of Scientific Unions (ICSU), with a new constitution under which a country could join one of the unions without necessarily first joining ICSU. In 1932 the International Mathematical Union was dissolved; but with the encouragement and assistance of Unesco, other unions were admitted to membership of ICSU—Crystallography (1947), Theoretical and Applied Mechanics (1947), History of Science (1947), Mathematics (reconstituted in 1952), Physiological Sciences (1955), Biochemistry (1955).

The original agreement between Unesco and ICSU was approved by ICSU in London in 1946, and has since been amended several times. At the outset Unesco awarded ICSU an annual subvention of $240,000, now reduced to $180,000. This grant enabled ICSU considerably to augment its efficacy from 1946 onwards, with a consequent increase in activity by the unions. Until 1954 the grant to ICSU was allocated to certain specific items individually, and transfers, however justifiable, were not permitted from one item to another without previous authorization from Unesco's Executive Board. Since 1954, apart from the appropriation for administrative expenses, the subvention has been a global one, to be used by ICSU according to its needs. This new arrangement has considerably enhanced the real value of Unesco's grant to ICSU.

Council of International Organizations of Medical Sciences

At its very first session, held in Paris in 1946, the General Conference of Unesco decided to encourage the formation of councils on the ICSU pattern for the medical and technological sciences, and in 1947 the Secretariat accordingly convened a meeting in Paris of representatives of the 17 medical congresses which had then resumed work. This meeting showed that the different branches of medical science could not be merged in a single body, and that the aim should be to co-ordinate them. A resolution adopted by the second session of the General Conference (Mexico, 1947) recommended that the action already initiated be continued. The Interim Commission of the World Health Organization (WHO) discussed this resolution at its fifth session at Geneva in 1948 and agreed to co-operate. It thus became possible to convene in Paris, on 12 April 1948, an organizing committee for a permanent bureau for the co-ordination of international congresses of medical sciences. A constituent general assembly, which met in Brussels in April 1949, drew up the statutes of the Council for the Co-ordination of International Congresses of Medical Sciences, which later became the Council of International Organizations of Medical Sciences (CIOMS).

The Council now has a membership of 50 international non-governmental organizations working in the sphere of medical science. Its principal aims are to obviate intellectual isolation due to over-specialization, to increase the efficacy of international congresses, to organize symposia bringing together different disciplines, to study questions suitable for joint action and to improve the international exchange of information. It relies for most of its income on grants from WHO and Unesco. The following table brings out the policy of steady gradual reduction followed in voting these grants (in dollars):

	1950	*1951*	*1952*	*1953*	*1954*
WHO subventions	35 200	35 200	35 200	29 000	25 000
Unesco subventions	27 750	23 750	21 000	19 500	18 000
CIOMS income proper	1 450	3 960	3 992	4 201	5 521

The main CIOMS activities are: making advance grants to congresses, to a maximum of $1,000 per congress, in order to facilitate the preparatory work; making grants for simultaneous interpretation and preliminary meetings of rapporteurs before a congress; organizing inter-branch meetings for representatives of the principal branches of medical science and publishing their records. Valuable as the CIOMS meetings are, there are inevitably very few of them, the Council's funds being so small; and it may be wondered how, in these circumstances, it can play the part it ought to play. At recent meet-

ings of the WHO governing bodies there have been signs that that organization may reverse its policy of gradually reducing its grants. The new policy may perhaps spell better days for CIOMS. Allowance must be made for these difficulties when CIOMS is reproached with being less efficient than formerly.

CIOMS might be expected to encourage the scientific spirit as the paramount factor in medicine. The list of its member organizations gives an idea of the difficulties to be overcome. No-one would gainsay the many additions to medical knowledge accruing purely from observation, or the results obtained in therapy by empirical methods; no-one disputes the importance of the psychological approach to the individual patient; no sensible person would dream of replacing the human element in medical treatment by an impersonal approach based solely on general scientific concepts. We cannot, however, fail to recognize the tremendous progress made in therapeutics since, scarcely a hundred years ago, the scientific spirit breathed new life into medicine by bringing it the benefits of explanation as practised in the natural sciences. We may hope that in time to come CIOMS will define the conditions required to ensure the right balance in medical practice between the consideration to be given to the patient's personality and that to be given to scientific explanation. In order to achieve this, CIOMS will need not only the collaboration of the international associations of medical practitioners, but also that of the international bodies concerned with the basic medical sciences. A proper balance of influence between these two categories of organization is an aim CIOMS must keep in view if it is to succeed in its own particular tasks.

Union of International Engineering Organizations

At the very first session of the General Conference, reference was made to plans for international organization in the sphere of engineering. In 1948 and 1949 the Secretariat carried out a series of preliminary studies which served to reveal the complexity of the way in which international relations were organized in this field. It became evident that there were two separate systems of international contact: a 'vertical' system, made up of international associations, each concerned with a specific branch, and a 'horizontal' system, consisting of national engineering organizations. These systems, which involved either permanent or intermittent contact, both overlapped and ignored one another, while the individual organizations found their objectives being steadily whittled down. Several aspects of international collaboration were being dealt with in fragmentary fashion or left unsettled, e.g.: the joint representation of all branches of engineering on a world-wide scale; the advancement of engineering knowledge by the dissemination and exchange of information; the universality of the engineering sciences.

In July 1949, a committee of experts convened by the Unesco Secretariat

agreed, despite the divergent opinions expressed during its meetings, to request Unesco to set up an agency to make recommendations to international congresses of engineers, prevent duplication and draw up a satisfactory schedule of dates for the different specialists' meetings. A conference of international engineering organizations met in October 1950 and prepared a draft constitution for the Union of International Engineering Organizations (UATI). The constitution was to come into force as soon as 10 organizations had joined the Union, and this took place in February 1951. UATI now has 13 member organizations: Permanent International Association of Road Congresses, International Institute of Welding, International Society of Soil Mechanics and Foundation Engineering, International Conference of Testing and Research Laboratories on Materials and Structures, World Power Conference, International Commission on Irrigation and Drainage, International Commission on Large Dams, International Association for Bridge and Structural Engineering, Permanent International Association of Navigation Congresses, International Association for Hydraulic Research, International Conference on Large Electric Systems, International Gas Union, International Institution for Production Engineering Research.

On 27 May 1952 UATI reviewed and adopted its constitution at its ordinary General Assembly. Its aims are defined as follows: 'To co-ordinate, by common agreement, the activities of the member organizations, and in particular the programmes and dates of their international congresses; to take all useful steps for the moral and material support of the member organizations; to receive proposals and to make recommendations thereon with a view to helping the formation of new international organizations in fields not adequately covered by existing organizations; to further mutually helpful relations among the member organizations and with similar organizations, and also relations between the member organizations and the United Nations and Specialized Agencies.'

UATI receives from Unesco an annual subvention of $12,000. Its activities include the publication of multilingual dictionaries of technical terms.

NEW FORMS OF INTERNATIONAL SCIENTIFIC CO-OPERATION

Institute of the Hylean Amazon

The laudable desire to set on foot new kinds of international scientific co-operation was expressed at the first session of the Unesco General Conference. At that session the Sub-Commission on Natural Sciences gave a favourable reception to a proposal from the Brazilian delegates for the establishment of an Institute of the Hylean Amazon. The programme for

1947 stated that Unesco would invite the governments of the different countries in that region (Brazil, Colombia, Bolivia, Ecuador, Peru, Venezuela, French Guiana, British Guiana, and Surinam) and the United States of America, together with other Specialized Agencies of the United Nations, to set up an International Scientific Commission to investigate on the spot the possibility of setting up an International Institute of the Hylean Amazon, which was to be a centre for the co-operative study of the scientific aspects of the problems of the equatorial forest zone. The Institute was to have the further aim of studying living conditions in the zone and contributing to their improvement.

Although, since it was first discovered, the Amazon region has been frequently explored, there has never been any co-ordinated or systematic effort of exploration. Tremendous opportunities for research exist in a wide range of subjects: types of wood suitable for building, medicinal plants, geology, mineralogy, meteorology. By the time the Conference held its second session, in 1947, investigations were so far advanced that the Director-General was instructed to convene a conference to establish the new Institute. This conference, convened by Unesco and the Governments of Brazil and Peru, met at Iquitos (Peru) in April and May 1947. A diplomatic convention was adopted, stipulating that the Institute would start work as soon as five signatory States had ratified the convention. The signatory States were Bolivia, Brazil, Colombia, Ecuador, France, Netherlands, Peru and Venezuela. Unfortunately, as ratification by five States was never secured, this splendid project ended in complete failure. The basic idea, however, was later revived in the form of a programme of research for the humid tropical zone.

Arid Zone Project

The failure of the Institute of the Hylean Amazon was a lesson to the Secretariat, since it revealed the difficulty of setting up, in a particular country, an international institute to carry out research covering, in some of its aspects, the natural resources of that country.

Consequently, when at the third session of the General Conference (Beirut, 1948) a group of Middle Eastern States displayed keen interest in the idea of establishing an Institute of the Arid Zone, the Secretariat proceeded with great caution. In December 1949, a committee of experts met in Paris to study the question, and took the view that it would be preferable to set up a Council for the Arid Zone. The committee's recommendations were circulated to Member States, and when their replies had been received, an Interim Council for Arid Zone Research met in Paris in 1950. This Council recommended the appointment of an Advisory Committee on the arid zone, and drew up a working programme, according to which the com-

mittee would consist of 10 members of different nationalities, appointed for three years and selected by the Director-General from among scientists and engineers of outstanding competence on the subject of the arid or semi-arid zone.

The programme has centred each year on one important problem: hydrology (1951-52), plant ecology (1952-53), sources of power available in the arid zone, particularly wind power and solar energy (1953-54), human and animal ecology (1954-55), arid zone climatology (1955-56). These studies have been published each year and have provided the subject-matter for discussions among specialists. In addition to these main studies the committee has encouraged the pursuit of many other activities, including the preparation of maps, and of reports on the purification and utilization of saline water, the past and present development of the arid zones, dew research, etc.

The National Commissions in the different countries may submit projects drawn up by their national associations. These projects are considered by the Advisory Committee, which on various occasions has suggested and obtained financial assistance for them from Unesco. Surveys are also made on institutions undertaking research on the arid zone, and on certain specific regions. Close co-operation is maintained with the other United Nations Specialized Agencies and with various non-governmental organizations.

The Arid Zone programme is developing smoothly and, it would appear, is giving general satisfaction. Co-operation with research institutes appointed for this purpose in the arid zone countries has not yet begun, but will proceed rapidly if the ninth session of the General Conference (New Delhi, 1956) adopts the Arid Zone programme as a 'major project'. In that case national committees for participation in the project would be set up in the different arid zone countries (more especially in the region extending from Egypt to India), and these national committees would act as guarantors of any agreement as to the aid furnished by Unesco to a scientific institute in the country concerned.

The Arid Zone project is not only important in itself; it represents, by the way in which it is planned, an important experiment in international co-operation and in the search for efficient methods of putting it into effect.

Humid Tropical Zone

The progress of the Arid Zone project shows that Unesco can successfully carry out an undertaking of this kind. After several years of specialized study, followed by a further advance into the realm of practical achievements (major project), Unesco might later hand over further work on the project to an international agency of its own choice. The experience gained in preparing the Arid Zone project should serve as a guide to Unesco in its new

international enterprise relating to the humid tropical zone. This is a scheme which revives certain very important points in the old Hylean Amazon project.

In 1946, the United Nations pointed out the utility of research on the humid tropical zone as a parallel to the study of arid zone problems, and the Natural Sciences programme adopted at the Montevideo General Conference in 1954 made provision for further studies of this subject. In February 1955 the Director-General asked the National Commissions to put forward the names of suitable persons to serve on an International Panel of Honorary Consultants. A survey of institutes engaged in humid tropical zone research had been made by the Secretariat in 1953 and 1954. A preparatory meeting of specialists on humid tropical zone research was held in March 1956 at Kandy (Ceylon), having been preceded by a symposium on methods employed in the study of tropical vegetation. This meeting drew up a number of recommendations, too long to set forth in detail, but embodying the following principal points: definition of the respective tasks of the committees on the arid and the humid tropical zones, and co-ordination of their work; study of a possible subdivision of the humid tropical zone into sub-zones; action for the encouragement of measures to preserve types of tropical vegetation which are in danger of destruction; continuation and expansion of bibliographies relating to regional vegetation; preparation of floras of humid tropical regions, with special reference to medicinal plants; studies of the entomology of those regions; consideration of their geology; collaboration with United Nations organizations already promoting hydrological studies; association of the meteorological services of the States concerned with the research undertaken; collaboration with organizations engaged on pedological research; inclusion of coral atoll ecology in the framework of studies of the humid tropical zones; studies of human physiology and health in the humid tropics; preparation of maps of fauna; preparation of climatological and vegetational maps.

The next meeting of the specialists' committee will be accompanied by a symposium on ecological studies of tropical vegetation in relation to soils. Fellowships will also be awarded to research workers wishing to specialize in research on the humid tropical zone so that they may acquire the necessary training in foreign institutes. Experts will be sent to Member States on request. These experts, appointed for a period of two or three years, will be supplied with the necessary scientific equipment and will have the assistance of local staff who can continue the work after their departure.

Marine Sciences

Resolutions on the marine sciences made their first appearance in the programme at the eighth session of the General Conference (Montevideo, 1954).

The ocean is essentially an international sphere, and in 1955 Unesco took the Arid Zone Committee as the model for an Advisory Committee on Marine Sciences set up to consider methods of developing the scientific study of the ocean and to supply organizations such as FAO with information which would lead to increased use of marine resources. The interim Advisory Committee met for the first time at Tokyo in October 1955. The experts invited by Unesco included Messrs. Bruun, Deacon, Rovelle and Zenkevitch and other authorities of international standing.

The committee of experts laid great stress on the sparsity of our knowledge of certain coastal regions (the coasts of the Indian Ocean, the east coast of Asia south of latitude 25° N, the east coast of South America north of latitude 40° S, and the west coast of South America). Among deep sea areas, we have little knowledge of the South Pacific and still less the Indian Ocean. The latter has even been said to be less known to us than the surface of the moon.

Recent advances in the basic sciences give hope of a very rapid development of our knowledge of the least explored regions of the ocean. All that is required is to make co-ordinated use of the new techniques. Provided that the staff of the research centre—which should work in close association with universities—does not fall short of a certain 'critical mass', and that it is supported by the governments concerned, it will be able to play a decisive part in the advancement of the marine sciences. One of the methods proposed is the construction of an international research vessel of between 1,200 and 1,500 tons, which might be operated jointly by a group of Member States. It is thought that this could accommodate six research workers recruited for a period of 12 to 18 months, and about fifteen students. The plans for such a vessel have been studied by a group made up of Bruun, Eyries and Deacon, and it is to be hoped that this excellent scheme will be successfully carried out.

INTERNATIONAL LABORATORIES

At the fifth session of the General Conference (Florence, 1950) the United States delegation put forward and secured the adoption of a resolution authorizing the Director-General of Unesco 'to assist and encourage the formation and organization of regional research centres and laboratories in order to increase and make more fruitful the international collaboration of scientists . . .'. Professor Isador Rabi, Nobel prizeman in physics, speaking as a member of the United States delegation, urged that the first centre should be established in Western Europe and devoted to nuclear research. In his speech at Florence, Rabi defined the idea of an international laboratory, and this definition later found its place in Unesco's doctrine concerning international co-operation. He pointed out that scientists in the United States of

America, and to a lesser degree in the United Kingdom, had at their disposal research facilities which for financial reasons were not available in the rest of Western Europe or elsewhere. The proposal was, therefore, that Unesco should undertake to combine the different nations in regional groups so as to enable them to set on foot research centres comparable to those existing in the United States of America. Unesco should serve as a catalyst for world science. He did not mean that Unesco should operate research centres, but that it should draw up the preliminary plans and see that they were satisfactorily carried out.

European Centre for Nuclear Research (CERN)

The proposal launched by Rabi at Florence was diligently studied by the Department of Natural Sciences in Unesco (whose head was, by a happy coincidence, a nuclear physicist) and was immediately taken up with great interest by a number of governments and the nuclear research institutions in the different countries. Plans were made for a European international laboratory; but it was evident that Unesco did not possess the resources to make a detailed design for the laboratory or meet the cost of construction. In 1951, therefore, the Director-General called a conference in Paris of representatives of the European Member States of Unesco. The conference met again in 1952 and set up an intergovernmental organ of inquiry—the 'Council of Representatives of European States for the study of plans for the establishment of an international laboratory and for the organization of other forms of co-operation for nuclear research', or, more briefly, the European Centre for Nuclear Research (CERN).

Unesco's role was not confined to the establishment of this Council, and it was understood that it would collaborate with CERN. The intergovernmental agreement of 12 February 1952 came into force on 2 May that year. The Organization in its final form was set up by the convention of 1 July 1953, which came into force on 29 September 1954. This convention has been ratified by the 12 signatory States: Belgium, Denmark, France, Germany, Greece, Italy, Netherlands, Norway, Sweden, Switzerland, United Kingdom and Yugoslavia.

Meanwhile CERN had drawn up a plan for the establishment of an international laboratory at Geneva. The work was divided between four study groups. At Copenhagen in June 1952 a conference attended by some 40 scientists from 12 countries adopted a programme submitted by these study groups. This programme called for the construction of two plants—a proton synchroton (now designed for energies of 25,000 million electron volts) and a synchro-cyclotron capable of accelerating protons to about 600 million electron volts. The first-mentioned will be the most powerful of its kind in the world. The second is a more familiar type of machine, which can be

constructed and got going more rapidly. Its chief purpose will be to produce an intense beam of mesons, which will afford many possibilities for research work by European physicists.

Construction of the laboratory began at Geneva two years ago, and the synchro-cyclotron is now being assembled. The Director-General of CERN is now Professor C. J. Bakker of Amsterdam University. CERN's budget for 1956 amounts to about 40 million Swiss francs. The total estimate for the building of premises and plant is about 200 million Swiss francs, and the cost is expected to be spread over a period of seven years, beginning with 1955. Funds will be obtained by contributions from CERN's 12 Member States, calculated according to a scale based on each State's average net national income. The scale will be reviewed every three years, but it has been agreed that no State shall ever contribute more than a quarter of the total budget. Until the end of 1956, contributions have been allocated as follows: Belgium, 4.88 per cent; Denmark, 2.48 per cent; France, 23.84 per cent; German Federal Republic, 17.7 per cent; Greece, 0.97 per cent; Italy, 10.2 per cent; Netherlands, 3.68 per cent; Norway, 1.79 per cent; Sweden, 4.98 per cent; Switzerland, 3.71 per cent; United Kingdom, 23.84 per cent; Yugoslavia, 1.93 per cent. Owing to budgetary difficulties, however, the contributions of Greece and Yugoslavia have been reduced to 0.35 per cent, the difference being shared by the other States (with the exception of Italy and Sweden) in accordance with the scale of contributions. Other States, in addition to the 12 founders, have applied for admission to CERN, but the Centre has decided not to consider any such applications before 1 January 1957.

International Computation Centre

The success of CERN justified its being placed at the head of our list of the international laboratories 'catalysed' by Unesco. Chronologically, however, another international laboratory preceded it in the history of the Organization. This was the International Computation Centre.

The creation of such a centre had been suggested at Unesco's preparatory conference in 1946. The project was, as already stated, included in the programme of the third session of the General Conference (Beirut, 1948), and in June 1949 the Director-General asked for the opinion of the National Commissions of the Member States on the subject. Studies continued throughout 1950 and 1951, and in December 1951 an intergovernmental conference was held in Paris, attended by representatives of 20 States (Belgium, Brazil, Denmark, Egypt, France, German Federal Republic, Iraq, Israel, Italy, Japan, Lebanon, Liberia, Mexico, Netherlands, Norway, Peru, Sweden, Switzerland, Syria and Turkey), and by observers from 8 other States (Austria, Colombia, India, Iran, Union of South Africa, United Kingdom, United States of America, and Uruguay). The conference adopted a convention

setting up the International Computation Centre in Rome, with the following functions: scientific research, education (training of specialized staff), advisory and computation services.

In 1952, the Italian Government set up in Rome a committee to organize the Centre, with the co-operation of the Unesco Secretariat, which concluded contracts with it for various technical studies on the equipment and installation of the Centre. The convention of December 1951 was to come into force as soon as it had been ratified by 10 States. At the present moment (July 1956), four and a half years after the adoption of the convention, only five countries (Belgium, Italy, Japan, Mexico and Ceylon) have deposited the necessary instruments entitling them to participate in the Centre. It is impossible not to contrast this very discouraging progress of the project for the Computation Centre, which the UN committees of experts regarded as potentially the most successful, with the rapid development of CERN in which the same experts had little confidence.

Cell Biology

During the eighth session of the General Conference, at Montevideo, a resolution advocating research into cell growth was introduced into the programme. A study group convened by CIOMS in Paris in 1955 made a number of recommendations, and various opinions were expressed by a group of consultants which met in 1956. At its third meeting (April 1956), the Advisory Committee recommended to the Director-General the inclusion of the following items in the programme for 1957-58: encouragement of interdisciplinary relations in the field of cell biology, a programme of symposia, fellowships and research, the establishment of centres for breeding pure lines of laboratory animals, and investigation of the possibility of creating a regional institute for the study of life under controlled conditions.

The proposed programme for 1957-58 submitted to the ninth session of the General Conference suggests that a meeting of experts be convened in 1957 to consider the possibility of establishing an institute for the study of plants and animals under fully controlled conditions. Consideration will also be given to the possibility of setting up centres for breeding pure lines of laboratory animals. The programme also proposes the convening in 1958 of a conference of government representatives to consider this project and, if appropriate, carry it into effect.

DISSEMINATION AND TEACHING OF SCIENCE

This began to take an important place in Unesco's programme at the fifth session of the General Conference (Florence, 1950). The chief activities in

this field are travelling exhibitions, a series of publications—inventories of apparatus and materials for teaching, manuals and textbooks—and the review, *Impact*.

Travelling Exhibitions

The first of these, organized in 1950, was designed to acquaint the public in Latin America with recent discoveries in physics and astronomy. The exhibits consisted of charts and photographs and also of apparatus enabling visitors themselves to conduct certain experiments. Its success (13 countries visited, 470,000 visitors) led to the organization of a series of travelling exhibitions: 'Our Senses and the Knowledge of the World' (since 1951): 8 countries visited (21 towns), 650,000 visitors; 'New Materials' (since 1952): 7 countries visited (11 towns), 630,000 visitors (is still touring Latin America); 'Man Measures the Universe' (touring Europe since 1954): 4 countries visited (6 towns), 200,000 visitors; 'Energy and its Transformations' (shown first in Paris, March 1956; will tour the Far East for three years).

In addition to these travelling exhibitions, Unesco has organized a number of non-travelling exhibitions on the following subjects: 'Man against the Desert' (shown at Jerusalem, 1953, during the International Fair, in collaboration with FAO, WHO and ILO); 'Zoological Gardens—Wild Life and Mankind' (shown in Indonesia, 1954); 'Balance and Unbalance in Nature' (prepared with help from Unesco by the International Union for the Protection of Nature); 'The Construction of Laboratory Apparatus for Schools' (shown in Cairo, 1955).

Unesco and the Member States have agreed upon a system for the division of liabilities arising out of the circulation of these exhibitions. Generally speaking, Unesco pays the salaries and travelling expenses of the managing staff accompanying the exhibitions, insurance on the exhibits, and transport costs to the frontier of the first State in which the exhibition is to be shown, while the receiving country defrays the cost of transport on its own territory and the expenses of organization.

Unesco's travelling exhibitions have everywhere been very favourably received. They are not only an excellent method of spreading knowledge of science among the general public, but are also useful as an adjunct to the teaching of science in schools. They supply excellent material for the preparation of photographs and filmstrips, which are circulated and utilized on an even wider scale than the exhibition itself.

Inventories of Apparatus and Materials for the Teaching of Science

This series of inventories will consist of 8 volumes. The first deals with the teaching of science in primary, secondary and vocational schools, the second

in universities, and the remaining six in technical colleges—veterinary sciences, physics and chemical engineering, agricultural science, medical science and training of mining engineers. Seven have already been published and the last is in preparation.

The model adopted is based on information assembled regarding the teaching of science in the countries generally considered to be the leaders in that field—France, Netherlands, Sweden, Switzerland, United Kingdom and United States of America. The inventory of the requisite materials is coupled with the syllabus of each course. The Unesco inventories have an interest far exceeding the problems connected with the equipment of school laboratories in countries in course of development. They supply very valuable information regarding science syllabuses at all educational levels. As these manuals are published in several languages (Volume I in French, English, Spanish and Chinese, and the other volumes in French, English and Spanish), they also form a valuable multilingual glossary of scientific and technical terms.

Textbooks and Manuals in Science Teaching

In countries where the teaching of science is still backward, the lack of educational equipment is the most discouraging factor. It was to help teachers in these countries that Unesco published in 1948 a little book by J. P. Stephenson entitled *Suggestions for Science Teachers in Devastated Countries*. Since then the Unesco Secretariat has found it necessary to supply manuals giving details of the construction of simple apparatus and the utilization of easily accessible natural materials for use by science teachers in the primary and secondary schools of countries where the teaching of science is developing rapidly. Unesco has also sponsored the publication by the Oxford University Press of a series of 10 manuals on science teaching in tropical countries, ranging from lessons in the rudiments of science to the higher grades of secondary education. They are planned for countries not yet industrialized, in which the pupil does not ordinarily come in contact with science in its applied form. Four volumes (in English) have already appeared. The manuscript of four others will be prepared in 1956. The two final volumes will go to press in 1957.

Impact

The full title of this quarterly periodical, published in French and English, is *Impact of Science on Society*. It is now entering its seventh year of existence, and for the last four years has been chiefly devoted to original studies of the social aspects of science. It is intended for a small but influential public, its purpose being to draw the attention of legislators, statesmen,

administrators and the organs of public opinion to the political, economic and social consequences and possibilities of science and technology.

ADVISORY COMMITTEE ON SCIENTIFIC RESEARCH

The seventh session of the General Conference (Paris, 1952) adopted a resolution authorizing the Director-General 'to establish an International Advisory Committee on Scientific Research with a view to promoting international co-operation between the national councils and centres of scientific and technical research in fields of common interest'. The Committee's terms of reference were enlarged by the Executive Board, which instructed it 'to advise the Director-General on research and related matters in the Natural Sciences programme of Unesco'. Twelve of its 15 members are 'representatives of the national research organizations sponsored or recognized by the governments of the Member States concerned', the three others representing ICSU, CIOMS, and UATI respectively. The 12 national members are appointed by the Director-General with the approval of the Member States concerned.

As will be seen, the Advisory Committee can be relied upon to put before the Director-General views which cannot be suspected of resulting from pressure by any particular scientific clique. Its members belong to governmental or government-recognized bodies and are selected by the Director-General. It is, therefore, particularly interesting to note the general policy laid down by the Advisory Committee at its first meeting in April 1954.

Realizing that the exchanges arranged by the international scientific organizations failed to ensure the full development of science on a really world-wide scale, the Committee stresses the advantages of co-operation in international research. It considers that each individual project in this field should be assessed from two points of view—that of its scientific and social interest, and that of the organizational apparatus required to implement it. From the administrative standpoint, it recognized three types of organization for the promotion of international research: intergovernmental institutions, international non-governmental institutions, national institutions having an international standing.

In the first category, government control may be direct (when the supreme authority consists of representatives of the member governments) or indirect (when authority is vested in intergovernmental bodies, e.g. the United Nations). The Advisory Committee therefore draws a distinction between intergovernmental institutions properly so called, and institutions of an indirectly intergovernmental character. While acknowledging the attractiveness of world research institutions, it recognizes that their establishment is attended by difficulties, as is shown by the vicissitudes of the International Computation

Centre. It is easier to set up regional intergovernmental institutions such as CERN.

An example of the indirectly intergovernmental organization is the Advisory Committee on the Arid Zone. The success of this type of institution is due in part to the wide range of subjects it embraces and in part to the fact that the research undertaken is mainly of interest to countries in course of development, where direct intergovernmental control would be difficult to achieve.

Examples of the second category of international research organizations, the international non-governmental institutions, are the Jungfraujoch High Altitude Research Station, the Naples Zoological Station and the Monaco Oceanographic Institute. The Advisory Committee holds that the international status of institutes of this type should be guaranteed by an international non-governmental organization of recognized standing, such as an international scientific union. Institutions of the required type might be set up for this express purpose, or, alternatively, the constitutions of some existing organization might be appropriately amended. A policy of subventions by the Specialized Agencies of the United Nations might help the international non-governmental institutions to expand.

The third category of international research organizations consists of national organizations having an international standing. These are agencies which, though their governing bodies are, strictly speaking, national, accept foreigners as advisers and research workers.

The Committee considers that Unesco can play a useful part by collaborating directly with existing laboratories, both national and international, by setting up bodies under its own administration to collaborate with a network of national laboratories, and by serving as a 'catalyst' for the establishment of new self-governing international institutions. One of the Advisory Committee's tasks will certainly be to revise the order of priority of international undertakings with a view to placing proposals before the General Conference.

The Advisory Committee on Scientific Research has so far held three meetings. It serves as a link between the various national research councils and enables them to work with the Director-General in the drafting of the proposed programme. Provision is also made for general meetings, from time to time, of all the representatives of the national research centres. The first took place in 1955 at Milan. Meetings of this kind help to stimulate the formation of new national research centres in countries where none so far exists. The activities of the Advisory Committee are thus an essential factor in the development of international co-operation.

FIELD SCIENCE CO-OPERATION OFFICES

The field science co-operation office idea was first mooted during the second world war, the object being to mobilize the scientific resources of the allied countries by promoting the exchange of information. One of these offices, set up at Chungking in China—the Sino-British Science Co-operation Office—was actively engaged in purely scientific tasks, and it supplied the model for the methods later adopted in the scientifically backward countries by scientific missions of the kind represented by the Co-operation Offices. Joseph Needham, with his first-hand knowledge as director of the Chungking experiment, was particularly well qualified, when he became Director of the Natural Sciences Division (now the Department of Natural Sciences), to impart to Unesco the impetus which gave birth to Unesco's Field Science Co-operation Offices.

The first programme, drawn up in 1946 at the first session of the General Conference, proposed the setting up of offices in China, Latin America and India, and defined their functions as being: to establish contact with scientists in the region concerned, to supply scientific information, to assist in correspondence on scientific questions, to provide the region with scientific publications and materials, to give assistance in problems of abstracting, microfilms, fellowships, etc., to disseminate scientific information originating in the region concerned, and to provide advisory services on scientific questions.

Three offices were opened in 1947—at Rio de Janeiro (Latin America), Cairo (Middle East) and Nanking (Eastern Asia). In 1948 the South Asia Office was opened at New Delhi, and in May 1951 the South-East Asia Office was set up at Jakarta, the East Asia Office being closed at the same time.

Latin America, the Middle East, South Asia and South-East Asia—all these vast areas are now covered by scientific missions from Unesco. The Latin American Office, set up at Rio de Janeiro in 1947, moved to Montevideo in 1949. It serves an immense area which immediately began to make active use of it, so that this Office has played a very effective part in co-ordinating and developing scientific research in Latin America by organizing meetings to study problems of special interest to that great region of the world, by training courses in modern research techniques, associations for the advancement of science, and science exhibitions. Many publications testify to the large volume of scientific information assembled by the Montevideo Office.

The Cairo Office, created during a period of political disturbance in the Middle East, received a less cordial welcome. Gradually, however, it has won the confidence of scientists in the countries it serves—Afghanistan, Egypt, Hashemite Jordan, Iran, Iraq, Lebanon, East Pakistan, Saudi Arabia, Syria, Turkey, etc. The first concern of the Cairo Office was to establish

scientific relations not only with the rest of the world, but among the countries within the group. Taking into consideration the principal interest of local scientific circles, it has concentrated chiefly on arid zone studies. It has also organized study meetings and responded to requests for assistance in thousands of individual problems, and arranged a considerable number of lectures by distinguished authorities upon being notified of their visit to the region by its information service.

The East Asia Office, opened at Nanking in 1947, served from the outset as the headquarters of a vigorous two-way current of exchanges between Western and Chinese scientists—the latter of whom had been cut off by the Chinese-Japanese war of 1931 from their foreign colleagues for nearly 15 years. Unfortunately, owing to the civil war, this Office had soon to be moved to Shanghai. In 1949 a branch office was opened at Manila, where it worked with ever-increasing activity from 1949 to 1951, whereas the work of the Shanghai Office gradually dwindled until its transfer to Manila in 1951. From that time, the Manila Office has been a dependency of the South-East Asia Office.

This was set up at New Delhi in 1948. It was warmly welcomed from the outset, and has ever since enjoyed the confidence of South Asian scientists. Its importance is shown by the strong feelings expressed by the Indian delegation when, during the eighth session of the General Conference (Montevideo, 1954), a proposal was made to close it in view of the progress achieved in the organization of science in India, and of the active relationship which India had developed with the Western scientific world.

The South-East Asia Office was established at Jakarta in 1951. It serves Indonesia, Malaya and Thailand. Through the branch office at Manila its work covers also the Philippines, Cambodia, Laos, Viet-Nam and Japan. At Jakarta there were exceptionally difficult material problems to be solved, and not until 1952 could adequate premises be secured. The Office is helping South-East Asian scientists to overcome many obstacles and is making every effort to co-ordinate their activities and, despite local political and economic difficulties, to uphold the principle of the practical importance of science and that of its intrinsic value and true character.

The scientific missions constituted by Unesco's four Field Science Co-operation Offices have adapted themselves to the evolution of Unesco's general policy and of its views as to the role the Organization should play. Since 1955 the Division of Field Science Co-operation Offices has been known as the Division of Regional Activities. In addition to its task of establishing relations among scientists, the Division has been invested with new functions to fit in with Unesco's present policy of satisfying requests for aid from Member States (Participation programme) and improved technical assistance. The new functions are: co-ordinating the work of the four offices, dealing with tasks under the heading of aid to Member States within

the framework of Unesco's own programme, and co-ordinating technical assistance projects.

The proposed programme for 1957 and 1958 lays down for each Office, in addition to activities already prescribed, a special line of work: marine sciences, humid tropical zone and peaceful uses of atomic energy for the Latin American Office; arid zone for the Middle East Office; marine sciences and peaceful uses of atomic energy for the South Asia Office; humid tropical zone and marine sciences for the South-East Asia Office.

Set up for purposes of scientific liaison and becoming by force of circumstance Unesco liaison offices, the Co-operation Offices are now situated at the centre of the latest trend in Unesco's policy towards direct participation in the efforts of Member States, at their request, and a more judicious implementation of the Expanded Programme of Technical Assistance. Thanks to the flexibility of their organization, the Offices will undoubtedly succeed in adapting themselves to any fresh developments the future may hold in store.

OUTLOOK FOR THE FUTURE

It may safely be said that international scientific activity is guided today by two organizations—Unesco and ICSU. The latter has gained new importance through the work made possible by the financial support it has been receiving annually from Unesco during the past 10 years. Relations between Unesco and ICSU during that period have remained excellent, their purpose being to increase the efficacy of scientific co-operation. While ICSU's chief task is to co-ordinate the work of the scientific unions affiliated to it, it is also anxious to initiate new forms of international co-operation.

The agreement concluded between Unesco and ICSU stipulates that the two bodies shall assist each other and consult on all questions within their joint competence. The annual subvention received by ICSU from Unesco is intended to facilitate the co-ordination of the activities of its member organizations and to supplement the financing of scientific projects of international interest in harmony with the aims of Unesco and included in the ICSU programme. For several years Unesco has, for instance, made ICSU an increased grant for the organization of the International Geophysical Year, the work of the ICSU Abstracting Board, etc. Unesco's Proposed Programme and Budget for 1957 and 1958 provides for the payment to ICSU of $22,000 annually for use by the Federation of Astronomical and Geophysical Services (FAGS), which will serve as a federation of permanent services concerned with astronomy, geophysics and the allied sciences. These are services permanently engaged in assembling observations and sponsored by various scientific unions—International Union of Astronomy, International Union of Geodesy and Geophysics, International Scientific Radio Union.

To provide all the services which might be expected of it, ICSU would undoubtedly need a larger annual subsidy from Unesco. Recommendations for an increase have been repeatedly submitted to the General Conference. Unfortunately, the objection frequently advanced on principle by a few delegations—especially those of the United Kingdom and the United States of America—to any increase in the total budget of the Department of Natural Sciences has hitherto militated against the granting of this increase. Those who are acquainted with the work done by the department and the duties awaiting it in the future, consider that to develop its full activity it should receive three times its present income.

Thanks to the two scientists who have successively directed it, giving it the benefit of their imagination, ingenuity, and thorough knowledge of scientific channels, the Department of Natural Sciences has made a great contribution to international co-operation in the field of science, alike from the theoretical and the practical points of view.

THE SOCIAL CHARACTER OF TECHNOLOGY

by

TOM BURNS

The author is Senior Lecturer at the Social Sciences Research Centre, University of Edinburgh. In the last few years, he has been engaged on research into industrial organization, and is now studying the implications for industry of technological change.

INTRODUCTION

The phenomenal growth of technology in the course of the last few decades is too obvious to need any elaboration. But perhaps no less significant than the rate of growth is the distinctive and novel character of contemporary technology. Briefly, the task of translation of scientific discovery into industrial innovation[1] is now the well-defined province of a new professional man—the technologist. Both the professionalism and the novelty of contemporary technology have important implications for industry at large.

The purpose of setting technology in these two frames of reference, institutional and historical, is to draw attention to two features of the present situation; first, that the growth of professional technology is associated not only with fundamentally different rates of progress in innovation but also with fundamentally different social processes; secondly, that the new situation is leading to profound changes in the institutional structure of the industrial enterprise.

This latter feature—institutional change in the industrial concern—partly follows, partly overlaps, other major changes in the structure of industry since the turn of the century. The most familiar of these is the change in scale; mass markets have created, and in turn been created by, techniques of mass production; the use of such techniques has made possible certain economies by mere increase in the size of plant.

Concurrently, with this increase in scale, there has developed a separation between ownership and control, between the holding of shares and the control of the policy and activities of a company.[2] This tendency is held to be as inherent in the structure of capitalist enterprise as is the tendency towards monopoly in the economy, arising as it does out of the division

1. 'It is important to distinguish between an invention, which is a technical or scientific fact, and an innovation, which is an economic fact' (Keirstead, *Theory of Economic Change*, Toronto, 1940, p. 133). An invention becomes an innovation when it is carried into commercial application.
2. Berle and Means, *The Modern Corporation and Private Property*, New York, 1932.

between ownership and use of property.[1] During earlier periods of capitalism economic power resided with the owners of the property, i.e. the shareholders. But the increase in the vastness and complexity of modern industry, the dispersal of shares among a multitude of small shareholders whose joint influence does not compare with that of a single compact minority interest, and the increasing importance of the managerial as against the financial element—owing to the technical and administrative complexities of modern large-scale enterprise—have transformed the relationship between owner and manager of productive capacity; power has been passing more and more into the hands of the management.

Both these developments have affected the economic and legal context of the industrial concern. Their influence on internal organization has been considerable. Increased size has made necessary the division of the general task of management into a multiplicity of individual tasks; the tendency has been towards an increase in such functions, each of which has become the province of a specialist—salesman, cost accountant, works manager, designer, planner, secretary trained in company law, personnel manager, production engineer. The development of these complex specializations and the increase in administrative skill and experience which they—and the growth in size of businesses—have called for, have both aided and been aided by the shift of control from owner to manager.

Essentially, however, the internal structure of business has not changed very much. It remains a singularly pure form of autocracy, absolute power (within the specific limits set by legal and social sanctions) being vested in top management, 'The Board', and exercised typically by a single person—the managing director. All powers vested in the company's organization are in principle regarded as his; they devolve upon others only by his express injunction, and are, in practice as well as in principle, revocable by him alone. However complex the links of subordination may be in the body of the organization, there is no question but that everybody within it is ultimately 'responsible' to the managing director; nor can any decision be made which is not subject to his approval. Indeed, in small enterprises, the practice is not unfamiliar for every letter and order to be signed by the managing director, or on his behalf. It is this internal structure which is now being subjected to strain—and thus induced to change—by the appearance within it of the professional technologist.

It would, indeed, appear self-evident that any institutional change in the relationship between industry and technology would inevitably lead to profound changes in the structure of industry, were it not for the odd tendency to disregard the fundamental dependence of industry on scientific discovery.

1. W. Friedmann, *Legal Theory*, London, 1949 (esp. p. 244); *Law and Social Change in Contemporary Britain*, London, 1951 (esp. p. 15).

Economic and organizational factors have bulked so large in the day-to-day life of enterprises that they have come to obscure the fact that the root stock of the industrial plant is technical innovation, however commonplace it may have become. It is only in historical perspective that we see and acknowledge the overriding importance of this relationship. A brief review of the institutional context of industrial innovation in the past may serve to underline the importance of that context and to point out the ways in which it has significantly changed.

INVENTION IN THE NINETEENTH CENTURY

During the middle years of the last century the electrical industry was established largely on the basis of supplying telegraph services. Within a few years the development of electric motors for tramways and stationary machinery led to very considerable expansion, and the need for the development of heavier and more efficient generating plant and distribution equipment accelerated the process. By 1880 there was a flourishing, keenly competitive electrical industry, not only in Britain and in the United States, but also in Germany, France and other European countries. Its technological base was very recent, and new applications and design improvements followed each other extremely rapidly. Yet the two major innovations during the last 20 years of the century—incandescent electric lighting and radio—were the work of newcomers, of inventors and enterprises unconnected with the existing industry.[1]

No spectacular 'discovery' lighted upon by an individual genius was really responsible for these two innovations. Electric lamps and wireless transmission were 'in the air' many years before the first commercial companies were floated. In 1860 Swan, a chemist, had made experimental incandescent lamps which employed the same high-resistance conductor—carbonized paper—as was used in the first commercial lamps marketed 20 years later.[2] By 1880, there were large industrial concerns manufacturing lighting and other electrical equipment; yet, in the event, it was Edison who, two years after becoming interested in the possibility, first developed the lamp and formed an independent concern to manufacture it.

As for radio, Lodge, following upon Hertz's earlier experimental work, demonstrated wireless reception before the British Association in 1894, and two years earlier a physicist had written in the *Fortnightly* of the 'possibility of telegraphy without wires, posts, cables or any of our present costly appliances', adding: 'This is no mere dream of a visionary philosopher. All the requirements needed to bring it to within grasp of daily life are well

1. W. R. Maclaurin, *Invention and Innovation in the Radio Industry*, New York, 1949.
2. A. A. Bright, *The Electric Lamp Industry*, New York, 1949.

within the possibilities of discovery, and are so reasonable and so clearly in the path of researches which are now being actively prosecuted in every capital of Europe that we may any day expect to hear that they have emerged from the realms of speculation to those of sober fact.'[1] Yet the development of this obviously profitable venture interested no commercial concern for 10 years. In America, the pattern was oddly repetitive. In the 1870's Graham Bell had tried to interest telegraph companies in the new, and rival, method of communication by telephone which he had invented; after unavailing efforts he founded the American Telephone and Telegraph Company. By the 1890's this company was the most research-minded concern in the industry. Yet it felt unconcerned about radio (apart from one brief and unsuccessful episode in 1906) until 1911, when the threat from wireless telegraphy was too strong to be ignored any longer. It was the 20-year-old Marconi who constructed, on the basis of Hertz's work as described in an Italian journal, home-made equipment which was sufficiently advanced after three years' work to communicate messages over eight miles, and to bring into being the Marconi Company.

Anyone who has read accounts of technological advances and inventions during the nineteenth century will perceive this pattern of development as in many ways typical. It is typical not only of the way in which invention 'happened' but, even more, of the way people thought it happened. Invention was seen as the product of genius—wayward, uncontrollable, often amateurish; or if not of genius, then of accident and sudden inspiration. As such, it could not be planned for and organized as part of industry—the idea was intrinsically absurd. In nineteenth-century Britain, the archetypal formula for the process of innovation was enshrined in the fantasy of Watt and the kettle.

The fitting of this myth to the key episode of the earlier technical revolution was itself characteristic. Of course, the myth of accident and inspiration did go some way towards accounting for the facts. And the outstanding fact was that the random dissemination of scientific and technical information through the new journals and institutions—and the continued exploitation of major inventions by craftsmen—made it seem possible for any individual innovation to be produced by almost anybody almost anywhere. If the disciplined attack on one difficulty after another—which is how the gap between the scientific idea and the ultimate product is bridged—was still intrinsic to the achievement, the process was nevertheless an individual, usually personal, enterprise. Images and myths had to fit these facts. So the boy Watt sat dreaming in front of a boiling kettle and later invented the steam engine. The essential condition of membership of a closely linked group of 'applied scientists' in the universities of Glasgow and Edinburgh,

1. See Maclaurin, loc. cit.

the special circumstance of friendship with Joseph Black whose discovery of latent heat lay at the bottom of Watt's improvements to the Newcomen engine, the presence of the industrialist Roebuck in the circle of personal acquaintanceship—these, the really significant factors, were eluded. These were social circumstances which could not be seen as essential conditions of the technological revolution at any of its stages.

In the latter half of the eighteenth century the Scottish universities were right in the centre, not only of the primal discoveries of the industrial revolution in chemistry and engineering, but also of the technical applications and of the commercial ventures which exploited them. The rapidity of technological development in the many fields which were being explored simultaneously in the laboratories of Edinburgh and Glasgow was the direct outcome of close personal association between people with different skills and different resources. But the association between people like Watt, Black and Roebuck was founded not so much on their membership of a common profession or organization, as on membership of a small, closely integrated society.[1] In eighteenth-century Scotland acquaintance of such men with each other was virtually inevitable.

It was such circles of personal acquaintances which served as a special medium for a further decade or so, and on into the nineteenth century, when fellow students and friends sought to institutionalize their informal acquaintanceships in the Lunar Society and the Royal Society of Edinburgh. These societies, together with their offspring in Manchester and Newcastle, and the archetype in London, comprehended the persons responsible for scientific advance, invention and, to a large extent, for innovation.

'Towards the close of the last century', says Smiles in his life of Boulton and Watt, 'there were many little clubs or coteries of scientific and literary men established in the provinces, the like of which do not now exist—probably because the communication with the metropolis is so much easier, and because London more than ever absorbs the active intelligence of England, especially in the higher departments of science, art and literature. The provincial coteries of which we speak were usually centres of the best and most intelligent society of their neighbourhoods and were for the most part distinguished by an active and liberal spirit of inquiry. Leading minds attracted others of like tastes and pursuits, and social circles were formed which proved, in many instances, the source of great intellectual activity, as well as enjoyment. At Liverpool, Roscoe and Currie were the centres of one such group; at Warrington, Aiken, Enfield and Priestley of another; at Bristol Dr. Beddoes and Humphrey Davy of a third; and at Norwich the Taylors and the Martineaus of a fourth. But perhaps the most distinguished

1. A. Clow and N. Clow, *The Chemical Revolution*, London, 1952, pp. 593-4.

of these provincial societies was that at Birmingham, of which Boulton and Watt were among the most prominent members.

'The object of the proposed (Lunar) Society was to be at the same time friendly and scientific. The members were to exchange views with each other on topics relating to literature, arts and science; each contributing his quota of entertainment and instruction.'[1]

But the rate of expansion of science and technology was too rapid to be accommodated by extension of these sociable institutions, vigorous as they were in middle class society at that time. The founding of the British Association in 1831, with its self-conscious attempt to institute an effective means of personal association between all scientists and technologists, may be regarded as marking the end of the period when a network of personal relationships was feasible.

MASS COMMUNICATION OF SCIENTIFIC KNOWLEDGE

What took the place of the group of people who were at once friends, fellow scientists and business partners, of the coterie whose common interests were at the same time scientific, technological and financial? It would seem that in the period roughly from 1825 to 1875 information about scientific discoveries became available to a wide variety of people. In fact, personal communication was replaced by mass communication.

The change from communication by speech to communication by print is an institutional change of a particularly potent kind. We are familiar with the part played by printing in accelerating the diffusion of information and ideas in the Renaissance and Reformation periods. A similar function as accelerator and diffuser (not cause) of knowledge may be ascribed to the appearance of scientific journalism in the nineteenth century.

The growth of scientific and technical journalism during the nineteenth century has often been pointed out. In Britain, the three phases of development are clear enough. There is the growth in the numbers of general scientific journals in the first quarter of the century, followed by the great expansion of specialist journals in the second quarter, and the further rise in the third quarter, accounted for largely by the publication of the transactions and journals of the learned and professional societies. Each phase originates in the preceding one.

In addition, clubs and institutes spread the new learning to ever-widening circles in industrial Britain, and lectures by eminent scientists became popular. Interest in science, even to the point of patronizing individual scientists or building a private laboratory, became something of a fashion.

1. S. Smiles, *Life of Boulton and Watt*, London, 1872, p. 367.

In short, the institutional process which we know as technology—the linking of scientific knowledge with knowledge of manufacturing operations, and of these two with knowledge of existing or presumptive demand—was spread at random among a very large proportion of the literate population. This meant that innovations might appear almost anywhere, might be lighted upon by almost anyone. To set up organizations which would systematically contrive innovations from scientific information—as happened in Germany—was almost ludicrously unrealistic to the British industrialist of a century ago.

The incoherence of the social institutions of technology at the time was reflected in the rudimentary ways in which innovations were socialized. Technological changes occurred largely through the birth and death of organizations, which is the simplest form of institutional change. Capital was plentiful, liquid and diffused, and was readily available for the exploitation of a new device or product. But normally, the institutional setting around an invention was rigid, clinging closely to the line of application and development originally conceived. New concerns had a fairly restricted expectation of life, even if they survived the highly lethal period of early infancy; 'clogs to clogs in three generations' is a piece of proverbial wisdom current in the oldest factory area in the world. The new devices which arose to render the old ones obsolete were generally exploited by new concerns. As Elton Mayo has remarked,[1] the small scale of business enterprises allowed this change to take place without too much dislocation of the social and economic order.

Invention could, and did, make big fortunes in an astoundingly short time. Technical limitations to large-scale production were such that the build-up had to be slow, and the manufacture of a single device, progressively improved, could absorb all the energies and resources of its designer and backers over a period of years. In these circumstances the economic, social and psychological resistances to the organization of research as an industrial asset, and of invention as an occupation of salaried professionals, were overwhelming. The story of Ferranti's weaning from the post he entered at Siemen's when he left school illustrates this attitude.[2] Ferranti had invented, at the age of 17, his first alternator. A meeting with another engineer, Alfred Thompson, led to an introduction to a London barrister.

> 'And you mean to tell me you're content to be at Siemen's', he said, 'earning £1 a week! Good God!'
>
> Lawyers see life on the seamy side; small wonder then that they become suspicious of all men.
>
> 'Ferranti,' he said, 'if you continue at a job like that, I'll tell you what will happen. As soon as they discover you've got an inventive ability they'll offer you £5 a week and proceed to rob your brains. You'll do the inventing and they'll collect the cash.'

1. E. Mayo, *Social Problems of an Industrial Civilization*, London, 1952.
2. Ferranti and Ince, *Life and Letters of Vincent de Ferranti*, London, 1934, pp. 51-2.

This was rather bewildering, but it chimed in with certain thoughts that had arisen in Ferranti's own mind.

'Perhaps I'd better ask for a rise,' he suggested.

'For God's sake don't do anything of the sort,' Francis Ince advised. 'Just clear out. That's no place for you. You might stay there till your teeth fall out and never get a dog's chance of doing anything. There's only one thing for you to do. You must start right away on your own.'

Ferranti objected that he had no capital.

'Leave that to me,' said his new friend.

Out of this meeting was born a considerable commercial enterprise which survived into the twentieth century to become part of modern industry based on technical information and professional technology.

The gap between invention and innovation which in the eighteenth century could be bridged by personal acquaintanceship was now spanned by technical and commercial adventurers. But even before Ferranti had his conversation with Ince, the situation was changing. The distribution of scientific information was rapidly becoming organized. The English provincial universities were founded in the second half of the nineteenth century, and the major scientific and professional societies were created during the same period.

By the end of the nineteenth century, science was the province of groups of specialists working in and supported by universities or quasi-academic institutions. It became separated more and more into different departments —chemistry, physics, geology, and all the later divisions and subdivisions. The driving force of this development was, of course, the sheer accumulation of information.

THE RISE OF PROFESSIONAL TECHNOLOGY

By 1900 scientists in universities were salaried professional men. Common to all professions is the maintenance of a hierarchy of power and privilege within the profession behind a front of uniform professional status *vis-à-vis* the lay public. This fosters the cohesion of the profession both by rendering success within it dependent as far as possible on the attestation by the members themselves of each individual's aptitude, and at the same time allowing all members to share in the public esteem won by individuals. Thus an important discovery in, say, plant physiology, becomes not only shared immediately as information by all members of that branch, but also brings prestige to the profession as a whole. In contrast, a technical innovation is usually patented, and is used explicitly for invidious comparison between members of the same industry. Professionalism, therefore, involves a substantial degree of dissociation from the society which is its support and context.

On the other hand, the situation of industrial technology was itself chang-

ing. Before the middle of the century, when the major scientific discoveries were the work of gifted amateurs and a few academic scientists, technically competent craftsmen like Mandslay, Nasmyth and Whitworth were able to create the machine-tool industry. The engines and machines that were the showpieces of the 1851 London Exhibition were largely the work of mechanics and master men who, thanks to the basic training of their apprenticeship, self-acquired mathematics and a clear grasp of the principles of the new engineering, had seized the opportunities presented all round them. Yet even then, development by improvement and new application was becoming a task beyond the capacity of men trained according to traditional craft methods. The outclassing of British products by European competitors at the 1867 Paris Exhibition made this quite clear. A Royal Commission was set up to survey technical progress in a number of countries, and by the opening of the last quarter of the century it was obvious that Britain had lost, or was losing, the technical lead established in the previous hundred years.

The answer to the problem was sought—as it always is—in improving and expanding the educational system. At this point, one may remark the different course followed in Germany. Although social distinctions were even more rigid and crippling in Germany than in Britain, Germany in one generation overtook and at many points outdistanced the technically advanced British industry. Many reasons have been put forward to explain this phenomenon. But whatever the reason, there is little doubt that the rise of German industry was the consequence of the energy and enthusiasm with which academic scientists, like Liebig and the members of the Berlin Physical Society, preached their technical gospel, or, like the Siemens brothers, themselves created industrial empires.[1]

Given this kind of liaison, the appropriate educational system followed. Without this liaison, as in England, the educational system—which was devised in imitation of the German one as it was thought—only served to reinforce the blockage of communication.

The whole context of industrial innovation had changed. Before 1850, the worlds of science and industry, though separate, could communicate with each other. The very existence, on such a large scale, of amateur scientific and technical inquiry demonstrates the ease of access to the world of science enjoyed by anyone with scientific interests. After 1900, science and industry became distinct social systems, entered by different routes and with very few institutional paths by which people or information could pass from one to the other. The need to cross this gap inevitably led to the development of new social institutions. The gap itself became a new territory, explored, mapped, and eventually controlled by new specialists, the professional

1. J. D. Bernal, *Science and Industry in the Nineteenth Century*, London, 1954; see esp. pp. 63-4 and footnotes pp. 77, 78, 144.

technologists, who went by the name of applied scientists, industrial scientists, chemical engineers and so forth.

Leaving out of account the prior development in Germany of a liaison established and purposefully maintained by the scientists themselves, the first successful venture of this kind took place not only outside Great Britain, but independently of both industry and established scientific institutions. Edison's Minto Park Laboratory, employing a hundred workers, was established in 1870 to turn scientific discoveries into industrial innovations. The concerns which later manufactured the new devices were financed and organized as separate ventures. But this earliest model was not followed until much later; no comparable organization was created in the U.S.A. until the founding of the Battelle Memorial Institute as a philanthropic gesture in 1929, and in Britain until the setting up of the Department of Scientific and Industrial Research in 1918.

In Britain and the U.S.A. research laboratories set up by industry itself came into being in the early days of the electrical engineering industry. Since then their growth has been rapid, and expenditure on research as well as the number of research workers employed by large industrial concerns have increased manifold in the last few decades.

In Britain, the development of industrial technology has depended very much more on government action than in the United States. This may be attributed, as it usually is, to the comparatively unenterprising character of British industry in the field of technical development, and to the unwillingness of entrepreneurs to undertake the risks of development work. Yet there were exceptions between 1900 and 1938, notably in the chemical industry, which had learned much from German methods and technological organizations—and which also enjoyed the greatest degree of stability.[1] However, the real explanation for this lack of enterprise lies not so much in the national character or the over-cautious attitude of the British entrepreneur as in his ignorance of the opportunities offered by scientific activity, an ignorance due to the lack of effective means of communication between the world of science and that of industry. By the end of the first world war the need for such means of communication was publicly acknowledged. Since industry itself was not supplying the intermediary technologists, the government in 1918 set up the Department of Scientific and Industrial Research. Between the wars, but especially during the last war, the government had to increase these technological resources very considerably in order to assure the translation of new inventions into military applications. It is from these sources that most of the industrial research and development effort in contemporary Britain has sprung.

1. Cases in point are Brunner and Mond, the United Alkali Co., and Nobel.

THE EXAMPLE OF RADAR

The large part played by the government in the development of the technical link between science and industry makes it somewhat easier to ascertain the more prominent characteristics of that link in Britain than elsewhere. Most of these characteristics appear in the history of the development of radar, perhaps the most spectacular outcome of government organized technology in Britain. For our present purposes, the critical features of radar development may be set down in brief form:

1. The facts about radio echoes had been known to scientists for decades.
2. In order to dispose of unfounded but persistent claims made about the feasibility of stopping aircraft engines by wireless 'rays' directed from the ground, the Air Ministry put a query to the head of the National Physical Laboratory. This elicited the response that the amount of power required for such a device rendered it entirely impracticable; but would the possibility of locating aircraft by radio be of any interest? The Air Ministry, which had been experimenting with sound reflectors as a means of locating enemy aircraft, pronounced itself interested, and started work in its own research establishment.
3. From the beginning of 1935 until 1937 all work on radar devices took place in the Government Research Station at Bawdsey. In the autumn of 1937 two radio firms were called in to manufacture equipment for the home chain of coastal radar stations.
4. A final factor in determining the nature of the war-time Telecommunications Research Establishment was the recruitment of university scientists which took place on the outbreak of war. This was a step of the highest importance for the organization of scientific effort. The scientists (mainly physicists) who came to Bawdsey represented a fair proportion of the younger leaders in their field. It was certain that their presence at the Telecommunications Research Establishment would attract others. It was also certain that the work of such a group of men in a promising field would achieve outstanding successes. Similar successes could have been achieved by the same men in other fields, and the decision to concentrate upon radar, even though it was partly the choice of the individual scientists themselves, was a notable example of the planning of scientific effort. It was these research men who, during 1939 and 1940, pressed through the work of evolving centimetric radar.
5. The general run of development technicians who remained in industry considerably improved their ability to tackle radar problems, but the scientists in T.R.E., who also advanced in technique and in the understanding of production problems, continued up to the end of the war to undertake at least the early stages of the design of new equipment and new variants of existing equipment.

All the essential features of the technological process are contained in this account.[1] First, there is the progress of scientific discovery itself, without regard for explicit use—an 'etherealized' system, to use Toynbee's word. Second, there is the direct communication link between user and scientist, leading to the definition of a need, and of technical information to meet the need. It is noteworthy that, in this case, the users' requirement was not formulated at the outset, but was the outcome of positive interaction; the first request was impossible to meet. Third, the main work of innovation was accomplished by scientists themselves, who took on the role of technologists. Fourth, until the end of the war, the role of industry was confined to manufacturing articles to new designs made in T.R.E.; the essential task of innovation was thus carried on outside industry—and was nevertheless effective. It was at least as effective as the design of aircraft, which was in the hands of aircraft firms, acting on the advice and working to the specifications of the Air Ministry, and using the research results of the Royal Aircraft Establishment, the National Physical Laboratory and the universities.[2]

It is possible to distinguish in this sequence a system of communication with the technologist at the centre, receiving information about techniques, needs, and resources respectively from scientists, users, and industrialists, and translating it so that it can be transmitted to all industrial, scientific, and user destinations. Direct and effective communication with all these is essential. Ability to translate information from a source so that it can be received and dealt with at its destination is essential. The location of the technologist himself is not important.

To elaborate this statement one may contrast the wartime organization of radar technology in Britain with that in Germany.[3] In Britain very close contact was established from the outset between the people in the Telecommunication Research Establishment and the serving officers in the Royal Air Force and officials in the Air Ministry. This system was consolidated at an early stage by the so-called 'Sunday Soviets' instituted by the then Superintendent. A 'Sunday Soviet' was an open meeting held every Sunday in the Superintendent's room, to which all Air Ministry officials and all Air Staff Officers were invited. The importance of the occasion as the main channel of communication was quickly appreciated, and each Sunday brought its galaxy of 'everybody from Air Marshals down'. A particular type of equipment or an operational problem would be selected, and leaders from both sides would be there to discuss it. There was thus a very intimate, personal connexion between those who had the operational knowledge and had

1. For more details, see J. D. Scott and R. Hughes, *The Administration of War Production*, London, 1955, pp. 378-9.
2. Scott and Hughes, op. cit., pp. 370-82.
3. This account is substantially that supplied by Mr. W. S. Robertson in a personal communication. Mr. Robertson was a member of the T.R.E. wartime staff, and towards the end of the war was engaged on a study of German organization of radar development and production.

actually to face the problems, who saw their men getting shot down every night and who themselves flew and got shot down, and those who worked in T.R.E. and had an intimate knowledge of the techniques and their possibilities. The result was that the laboratory workers got an immediate emotional as well as intellectual appreciation of the pressing operational needs, difficulties and problems, which they could never have acquired through written requests and reports. Equally important, the operational people began to acquire notions of the potentialities of the techniques which they could never have gained except by direct personal contact with the people who originated them. Thus by confronting scientific possibilities with operational needs at the top level in an intimate, personal, informal way, it was possible to achieve the speediest application of techniques to operational problems.

In Germany, a great deal of radar development had been done before 1939, and some equipment of an advanced type was in mass production by 1939, but work on development was virtually stopped because it was thought there would be no further need for it. When the Germans did start up again, they appointed a Plenipotentiary for High Frequency Techniques. This Plenipotentiary established a chain of new research institutions. He also introduced a system of recording all the available laboratory resources, not only in his own institutions, but in all the industrial firms, the universities and the technical colleges in the country. He then established contact with an official at his own level in the Air Ministry. The latter would define specifications of what the Air Force wanted, and these would go to the Plenipotentiary for High Frequency Techniques, who would consult his list and see which laboratories were unemployed; then he would post off the specification to one of them. The laboratory would thereupon make equipment designed without any real knowledge of the operational needs, which would therefore in most cases not meet those needs. But much more serious than these deficiencies was the fact that most of the potentialities were not realized, because the operational people could not possibly envisage the potentialities of available techniques, while the technicians had no means of seeing the problems of those who were flying the machines.

There is no reason to believe that the Germans, at the outset of the war, were technically inferior either in research or in production methods, or that they were lacking in resources. The clue to the strong lead which Britain obtained and held lies unquestionably in the appreciation of the supreme importance of bringing technical knowledge into close contact with the user's requirements.

The same kind of link was also established with the manufacturer. By having to supply requirements, which were laid down by the research establishment and for which specifications normally involved discussion and explanation, the management of the firm would get to know about other

requirements and thus would broaden the basis of its development work and production. There was nothing in the way of formal meetings or of correspondence. In a number of cases, the work of a small group of technical experts in one of the research establishments became responsible not only for a large volume of eventual production by an industrial concern, but also for the provision of a great deal of the necessary technical information. What really counted was personal contact.

TECHNOLOGY INDEPENDENT OF SCIENCE AND INDUSTRY

The situation in which the process of technological innovation occurs today is radically different from that of a generation ago. Yet technology is still seen by many of the people intimately concerned with it in terms of the situation of 75 years ago. As Bernal has said recently, 'Many intelligent non-scientific people still think of science as it appeared to be in the nineteenth century, as the product of individual men of genius, instead of, as it now is, a highly organized new profession closely linked with industry and government.'[1]

Of course, radar development took place under the stress of war; and by far its greater field of application was, and is still, military. But these considerations, though they qualify it, can hardly invalidate the conclusion to be drawn from the technological case-history of radar. True, the account has unusual features: scientists were prepared to turn themselves into technologists for the duration; there was a user—the government—who could not only specify clearly what was wanted but also control the whole system by which it could be provided; and so forth. But this is not something different from other technological developments. The components—scientific discovery, industrial concerns, demand for innovations, and communication systems linking all three—are familiar enough in other contexts. The main peculiarity of this illustration of the contemporary structure of technology is its lucidity.

Nowhere is the radar case-history more explicit than in showing the complete independence of the technologist from industry. True, as time went on and technologists *within* industry learned more of the techniques, rather more of the work of developing designs was handed over to them, and after the war this process of dispersal was further accentuated. But the role of T.R.E. in the days of most fertile development, of most rapid growth, exemplifies the possibility of designs for manufacture being formulated adequately *outside* industry, and not on a once-for-all basis but as a continually evolving process. Thus the crucial stages in industrial innovation cannot be

1. J. D. Bernal, loc. cit., p. 4.

regarded, in any sense, as being necessarily a part of the entrepreneurial function. In fact, technology now exists as a system separate from both science and industry. It has emerged as a profession, much as science did in the latter part of the nineteenth century.

Technologists are normally people who, having graduated in science at a university, have served a period as junior members of a development or design team in an industrial or government laboratory. What counts is not the character of their employer, but the character of their work, i.e. membership of the appropriate system of communication—in electronics, biochemicals, fibres, nucleonics, metallurgy, aeronautics—through which flows information which may contribute to the development of any innovation. The comparative independence of technology from industry is reflected in the comparative independence of the technologist. The status of the technologist is a professional one, and there is fairly precise equivalence in rank as well as salary between the organizations employing technologists. They move freely—and would like to move much more freely—between posts in governmental, university and industrial establishments. The career is not restricted either by the motive of 'loyalty to the firm' or by that of 'best prospects' within the firm.

For the individual firm, the technologist is an alien element; he does not fit into the factory system in the same way as other functional specialists, who are each a small but integral part of the general managerial entrepreneur function. But the technologist, by reason of his training, skill and actual knowledge, has value also outside the firm. This lies at the bottom of the differences in manners, behaviour, dress and language which so clearly distinguish the technologist from the other members of the firm, and which can raise minor problems of organization.[1]

Yet technological development is of vital concern to the individual firm; and the increasing pace of innovation makes it inevitable that the firm will have to provide more and more support for technological activity as a condition of its own survival. Thus the type of organizations which support and use the innovator has changed with the institution of technology.

Today, with so much capital and so many social obligations involved in industrial concerns, change can no longer be allowed to occur through the elementary birth and death cycle usual a hundred years ago. Firms employing many thousands of people cannot close down without wrecking large areas of social organization. Such concerns must keep alive, and in order to do so they must become adaptable to changes.

The closer an individual firm comes to enjoying a monopoly, the more its

1. The organizational problems consequent upon the employment of technologists within the firm are the subject of a study now being conducted by G. M. Stalker and the author, as part of the research programme of the Social Sciences Research Centre, Edinburgh University. The study is supported by the Department of Scientific and Industrial Research with a grant from funds made available to the United Kingdom under Conditional Aid.

policy is governed by the necessity for survival. Keirstead introduces a lengthy exposition of actual pricing policies employed by a 'giant multi-product corporation' as follows:[1] 'When we define time concretely in terms of the processes of which it is constituted, we are obliged to ask whether the firm aims at a maximum temporal rate of profit . . . or whether it aims to obtain the largest estimated profit over some (indefinite) period of time. I am convinced that the latter notion is . . . more in accord with real facts of actual situations. . . . The maximization of profit at any moment may result in the appearance of competitors whose supplies would reduce prices to the point where total net profits over a sufficient period would be reduced below what they might have been had a lower rate been accepted and the potential competitors kept out of the market.'

From our point of view, the interest of the passage lies in the light it throws on the overriding need to keep the firm in being. As soon as the realities of industrial enterprise are considered in terms of the individual firm rather than of the individual entrepreneur, then almost any profit upon which the firm can survive becomes preferable to larger profits on which it might possibly not survive. For an individual entrepreneur, profit-taking can be maximized for however short a time, since the rewards will certainly be a substantial help towards his own personal survival. Moreover, in the case of the individual, the random range of circumstances affecting his strategies increases enormously with time. But in the case of the corporation, time does not increase randomness at anything like the same rate; and survival means survival of the firm, not of an individual. The birds in the bush—which are tomorrow's or next year's production—are just as important as the one in the hand.

Even expansion must be considered in terms of survival. It is a commonplace among the major concerns of the electrical engineering industry, for example, that expansion of the single firm should be geared to the expansion rate of the whole industry, the rough indicator being the rise in the consumption of electricity. No firm wishes to expand at a smaller rate; but equally no firm wishes to expand at a greater rate, since this would involve a reduction in the expansion rate of competitors who might retaliate by a price war. More important for us is the fact that innovations, which are essentially cost-reducing in their effects, fall within the category of actions related to survival rather than to maximization of profits.

THE EXAMPLE OF THE SCOTTISH ELECTRONICS SCHEME

The general tenor of the argument may be illustrated and given point by reference to a co-operative scheme for technological development in elec-

1. Keirstead, loc. cit., p. 254.

tronics now being conducted in Scotland under the auspices of the Scottish Council (Development and Industry) and of Ferranti Ltd., with government support. This electronics scheme now involves about half a dozen firms from different sectors of the electrical and mechanical engineering industries. Each of these firms is engaged on parts of contracts divided between themselves and Ferranti Ltd., which have been or are being started in the Ferranti laboratories. In each case the incentive is not the development contract itself—which allows only a very small margin of profit—but the production contracts which may follow the completion of the development contract and, even more important, the cultivation of novel techniques inside the manufacturing plants of each firm. Thus, there are two assumptions now being made which, we believe, are consequences of the new relationship of technology with industry.

In the first place, innovation is the expected, 'natural' outcome of the work of a number of professional technologists in applying specific techniques to solve the specific problems of a user.

Secondly, innovation is not in any sense dependent on the efforts of individual entrepreneurs. Development groups are 'grown from seed' in a central laboratory, and then planted out in laboratories provided by industrial firms. Here they are expected to bring to fruition the innovations required by the 'seed growing' agency, and to generate other innovations by this association with the technical management—sales and production—of the new firm. But the functionally significant links of the development team—those which keep it alive—are its links with other development teams, with the general system of technological development, and not with the particular firm. If a development team can be grown in one firm's development laboratory and transplanted into another firm's laboratory, then it can also be replanted anywhere. In short, it exists as a quasi-independent organism within the individual firm.

This latter assumption, and its corollary, is given substance by the history of the growth of the scheme. The electronics scheme was the outcome of a series of discussions between people within the profession of technology. At intervals the proposals for action formulated by those operating within the given technology were sanctioned by the organizations outside the technological structure, i.e. by administrative officials and ministers, and by industrialists.

What are, then, the supports of the technological structure, if they are extrinsic to the individual concern? So far as the main development activities of the present electronics industry in the United Kingdom are concerned, support comes in practice either from major industrial concerns or from government departments. In both cases it comes from the organizations which cater for user needs on a national or near national basis.

In Britain the government has the dual role of user and representative of users. The clearest illustration of these roles is the defence programme, on

the one hand, and the activities of the Department of Scientific and Industrial Research, the Ministry of Agriculture and Fisheries, the Medical Research Council, etc., on the other. But there are also very substantial development programmes maintained by industry independently of government support —for example, in many chemical and metallurgical fields, and in commercial television. In general, research and development in these fields is the province of the major concerns, that is, of those concerns which can devote a substantial part of their profits to the exploration of user needs and to the development of materials and other products which will satisfy them. In these cases user needs are represented by the market forecasts of giant monopolistic or 'oligopolostic' firms, acting in anticipation of the profits which will accrue when those needs are met by the technologists.

The incorporation of professional technological development groups in a firm means that the firm is committed to a future which is in the hands of the technologists to determine. In many industries, civil as well as military —aircraft, electronics, fibres—development is largely self-generating, and obsolescence is a technical rather than a material fact.

In effect, therefore, we have to postulate a closed technological structure, in that the needs which the technologist satisfies are themselves the product of technological exploration. This closed structure is demonstrated most clearly in the contemporary development of civil and military aircraft, and in television, but it is universally true of technology. In fact, it always has been true. The novelty of the contemporary situation lies in the fact that the technologist, even when he is commuting between factory workshop, industrial development laboratory, government research establishment, and university laboratory, is a member of a social system independent of these, in which he is closely integrated and professionally organized. In these circumstances, technology appears as a system extraneous to industry, yet essential to the survival of individual firms.

CONCLUSION

To sum up: two major changes have occurred in the social circumstances affecting the introduction of innovations. In the first place, industrial firms have increased in size so much that their survival is now a matter of far greater concern, not only to themselves but to society, than it ever was before. The chances of a firm's survival are improved if the technical innovations which might render its processes or products obsolete are developed within it and not outside it. The other change relates to the institutional environment in which invention is generated. In the eighteenth century familiar and sociable relationships provided adequate communication for ensuring the major syntheses of ideas and requirements from which the early

revolutionary inventions originated. But the scale of scientific and industrial activity rapidly outgrew the social institutions within which the industrial revolution was generated, and new institutional forms introduced barriers between science and industry, between 'pure' and 'applied' science, and between different departments of science. The syntheses which produced inventions and innovations thus tended to become random. This incoherence has now given way to a new and elaborate organization of scientists and technical innovators into professional groups which overlap teaching and research institutions, government departments and agencies, and industry.

Neither change is complete. Nor are the contrasts as yet very clear. Few sectors of industry, outside chemicals, have fully accepted the changed situation. It was still possible, in the years between the wars, for a major innovation like the gas turbine to be developed in ways reminiscent of the classic days of nineteenth-century back-parlour invention. The invention of the jet engine depended primarily on an individual's persistence and enterprise, though the new massive organizations of government and industry were also involved.[1] On the other hand, the career of the most publicized inventor of the nineteenth century, Edison, reflects the characteristics both of the previous epoch—in the almost conscious exploitation of sociable contact with scientists and technologists—and of the later epoch—in the creation of development groups and professional careers in invention. Yet the process of change is far enough advanced for the new characteristics to be discernible. The present period is obviously one in which technological development is proceeding at a far more rapid pace than ever before. It is also one in which technology, organized as a specific social institution, is moving more and more into a controlling position. The major changes imminent in the economic structure of society are likely to derive more from the expansion in size and power of the technological system than from overt political strategies.

1. Sir Frank Whittle, *Jet*, London, 1954.

BOOKS AND PUBLICATIONS

Fifty Years of Medical Research

Medical Research: A midcentury survey. Edited by Esther Everett Lape and Associates. Published for the American Foundation by Little, Brown and Co., Boston, 1955, 2 vols., 1,505 p., $15 the set.

Later generations, viewing the times in which we live from the longer perspective of history, are likely to recognize the first half of the twentieth century as the period in which society first felt—for good or ill—the full impact of progress in the natural sciences. The application of scientific knowledge and methods to man's common activities and needs can be traced, of course, to much earlier beginnings. But the richness of the closing decade of the nineteenth century in major discoveries of the kind from which science advances with fresh impetus and in new directions seems to have caused a sudden acceleration of the process about the turn of the century. In no department of knowledge and practice has this change been more conspicuous or more rapidly progressive than in the general field of medicine.

The end of the nineteenth century found medicine still a body of largely empirical knowledge growing mainly by slow accumulation from the direct study of disease at the bedside and of its results in the post-mortem room. Sir Henry Dale has described how, when he entered upon his undergraduate clinical studies in 1900, he received warning that it was his duty to forget the teachings of the experimental science of physiology and to accept those of medicine, as still an empirical art. Medicinal treatment consisted largely of tonics, purgatives, diaphoretics and analgesics. These remedies had almost all come into use as the result of empirical observation. Their reputation in the majority of cases was based on practical experience and tradition, or even on vague general impression. The accepted purpose of treatment was that of assuaging the symptoms of disease, leaving a radical cure, if any were possible, to the *vis medicatrix naturae*. The idea that a remedy could directly remove or neutralize the cause of an illness was never entertained, and neither physician nor patient had yet learned to expect a medication which would go in this way to the root of the trouble. Pharmacologists concerned themselves chiefly with the detailed analysis of the actions of remedies which tradition had brought into use; and even on these lines the potential contribution to medical practice was seldom obvious. There was at least some justification for the clinician's familiar gibe—'healthy frogs are not sick men' —as well as for the pharmacologist's lack of interest in a therapeutic practice

which used so many drugs with no demonstrable action for purposes so ill-defined.

Compare this state of affairs with that of today. In every hospital standard diagnostic equipment includes X-ray apparatus, electrocardiographs and other scientific equipment that was beginning to be used in a few experimental laboratories 50 years ago. Many diagnoses are made only after physical and chemical investigations have been undertaken. We have become so accustomed to the effective and radical treatment of diseases which until recently were beyond the reach of remedy that there is a tendency to regard the existence of others as a reproach, as well as an incentive, to medical science. Pneumonia, puerperal fever, meningitis, typhoid, typhus, dysentery, gonorrhoea, syphilis, pernicious anaemia, diabetes, myxoedema, scurvy, rickets—these are no more than a sample from a list of diseases now brought under such rational and effective treatment that the whole attitude to them, of the public as well as the medical profession, has completely changed. It can hardly be doubted that this aspect of medicine has been the subject of a greater advance since the present century began than in all the centuries before it. Those who remember the position even 35 years ago will recognize the contrast between the prospects of sufferers from, say, diabetes or pneumonia then and now.

Let us review in outline some of the main developments in the medical field and then consider, first, how they have altered the attitude of the profession and the public to medical research, and second, their impact on two types of society, that of highly developed industrial countries like Western Europe and the United States, and that of relatively underdeveloped areas like most of Africa and Asia.

The use of immunization against smallpox goes back, of course, to Jenner and the eighteenth century. In the early years of this century the same principle was applied to combat several other diseases. The value of Wright's typhoid vaccine had been established before 1914, and the widespread use of this vaccine was probably the main factor leading to the striking contrast between the almost negligible mortality from enteric fever in the armies of the first world war and the tragic experience in South Africa, where the disease had been more fatal than the Boer bullets. Immunization against diphtheria—combined, probably, with a diminished virulence of the invading organism—has caused a very striking fall in the toll from the disease in all Western European countries. In England and Wales the death rate per million from diphtheria was 244 in 1898 and only 4 in 1948; but we have no reason to be proud of anything less than complete elimination of this menace to the life of children. There are large communities already where systematic immunization has caused the total disappearance of diphtheria. The experience of the city of Hamilton, Ontario, can be cited as an example.

The incidence of and mortality from diphtheria had shown for years only minor fluctuations up to 1925, when general immunization was instituted. Then both fell so steeply that in that large population there has been no death from diphtheria since 1930, and no case of the disease since 1933. In the face of results like these it is difficult to have sympathy with people who believe themselves more than commonly humane and yet conduct campaigns to frighten mothers into refusing for their children the protective inoculation against diphtheria.

An equally conspicuous success followed the systematic active immunization against tetanus of armies engaged in the second world war. The efficacy of vaccination against yellow fever was also tested under critical conditions when thousands of British and American troops, later exposed to infection in Africa, were vaccinated. Many millions of people have now been vaccinated, especially in South America, and this measure, together with elimination of vector mosquitoes, has resulted in the virtual eradication of the disease from large areas where it was once a major cause of mortality. Other methods of immunization have had less spectacular results, but they have also proved their worth in carefully controlled clinical trials embodying proper statistical evaluation of results—which are in themselves an innovation. Among these may be cited the inoculations against whooping cough and tuberculosis, and it is to be hoped that poliomyelitis will soon be added to the list. Other attempts at immunization have met with less success: the protean nature of the influenza virus, for example, has so far prevented the development of a really satisfactory vaccine against the disease.

Even before the end of the nineteenth century Paul Ehrlich was laying plans to apply the new science of organic chemistry in synthesizing artificial remedies which would deal specifically with infectious agents. Systematic tests were not possible on occasional cases of disease in man: the campaign was really opened when Laveran and Mesnil discovered that trypanosomes responsible for various animal and human infections in the tropics could be maintained indefinitely by serial passage in rats and mice. The researches of Ehrlich and his school led to the discovery of 'germanin', which was for long the best practical remedy for sleeping sickness. The same experimental approach resulted in the isolation of 'salvarsan' for treatment of syphilis and of several potent anti-malarial drugs (e.g. plasmochin, atabrine, daraprim, and chloroquine). Parallel developments have taken place in the use of insecticides and other means of eradicating the insect vectors of disease. The major protozoal diseases are now, in principle, 'conquerable'. The application of measures already available for their control in the vast underdeveloped countries, where these diseases are endemic, presents problems which are social and economic rather than purely medical.

For more than half the period under review hardly any success, and none that was practically convincing, had resulted from many attempts to extend

chemotherapy to the ordinary bacterial infections. Ehrlich had encountered an early check in this direction, and his successors fared little better; so that an opinion had come to be held, and seemed to be hardening into a conviction, that except for certain widely spread spirochaetal infections like syphilis, the prospect for chemotherapy would still be limited to the treatment of protozoal infections, and therefore chiefly to that of tropical diseases; while immunology, it seemed, would continue to provide the specific remedies for the bacterial infections predominant in our temperate climates. Then, in 1935 and the years immediately following it, this picture changed completely. The scope of chemotherapy underwent a greater and more rapid change than any therapy had ever done, and with strong reinforcement by a new advance from another direction it continues to this day. In 1935 Domagk published his evidence of the effective action of the red dye 'prontosil' against streptococcal infections in human cases as well as in experimental mice. A series of sulphonamide drugs was soon available, effective against most pyogenic infections—e.g. pneumonia, puerperal fever, meningitis and gonorrhoea. Thus the prospect of sufferers from a whole range of the commoner bacterial infections was transformed in a few years.

Long before the possibilities of the sulphonamides had been fully developed, another chemotherapeutic method against bacterial infections became available, from a quarter widely separated from the synthetic approach adopted by Ehrlich and his successors. The story has been told so often that it need not be repeated here in detail of Fleming's discovery of penicillin through the action of a mould colony which by accident contaminated a plate culture of bacteria, and of his partial exploration of its properties in 1929; and then of the further initiative of Florey, Chain and their co-workers in 1939, which led to the purification of penicillin and to the demonstration of its outstanding practical value as a therapeutic agent. The urgency of war had much to do with the rapidity of the development from laboratory experiment to large-scale production. With the resources thus made available, and intimate co-operation of scientists in Britain and the United States, penicillin was soon separated into several closely related compounds, their structure was determined and one was artificially synthesized. In the next decade several other potent antibiotic substances were discovered (notably streptomycin, choloromycetin and aureomycin) which have proved highly effective against most of the bacterial diseases untouched by sulphonamides and penicillin and also against some virus diseases.

In another field—that relating to the recognition and replacement of deficiencies in the diet and in the internal bodily secretions—the achievement has been no less spectacular. The treatment of scurvy with fresh fruit and vegetables seems to have been discovered and rediscovered in each of several earlier centuries, and even the use of cod-liver oil for rickets had long been recommended empirically. The recognition, however, that a natural

diet contains small quantities of a number of accessory factors, to which —often inappropriately—the name 'vitamins' has come to be applied, and the exact knowledge of the diseases of deficiency resulting from the lack of one or another of these in the diet, all these are achievements entirely of the present century. The paper of F. G. Hopkins, from which many would date the beginning of systematic investigations in this field, was not published till 1912. E. Mellanby's investigation producing the first clear evidence that rickets is due to the lack of such a factor in the diet, and that this is a fat-soluble vitamin contained in cod-liver oil, was published in 1919. Almost all the investigations by which the vitamins responsible for different aspects of growth and metabolism have been chemically isolated and identified were carried out in the two decades between the two world wars. The most recent isolation came in 1948, with the practically simultaneous crystallization in the U.S.A. and in England of vitamin B_{12}, which acts in doses of only a few micrograms to replace the factor missing in pernicious anaemia. The dietory factors needed for proper growth and development are now well known, so that the provision of an adequate diet in any population poses agricultural and economic problems, not primarily medical ones.

Among the hormones or internal secretions that have been more or less completely isolated and used therapeutically during this century may be mentioned thyroid hormones for treatment of myxoedema, adrenalin, posterior pituitary fractions, insulin for treatment of diabetes, parathyroid hormones, various sex hormones, adrenal cortical hormones and anterior pituitary hormones.

In the course of these developments the practice of medicine and its relationship to the experimental sciences has been revolutionized. Medicine has not only drawn ever more freely from an ever-widening range of the experimental sciences for its own practical purposes, but has also, in the process, become so permeated by their methods as to have become largely an experimental science in itself. There has been a concomitant advance in the general estimate of what medical research is worth and of what it can be expected to do. These have raised its status from that of a spare time enterprise for the rare and unworldly devotee in 1900 to that of an activity to be encouraged and supported, as a career in itself, for a minority having a special attitude. But it is now also desirable in the experience and credential of every aspirant to distinction in clinical teaching and practice as we find it today.

This point is endorsed by the report of the American Foundation on Medical Research which is under review. This report is intended to be an assessment of the present status of medical research in the United States by an objective non-medical research agency that has public confidence. It follows a previous report of the Foundation—on medical care and how it is paid for in the United States of America. From this study the conviction

emerged 'that it is useless to discuss the administrative problem of distributing medical care and the economic problem of paying for it without reference to the central need of having a sufficient number of trained physicians capable of providing a type of medical care that can justify elaborate plans for distributing it and paying for it. We are convinced that the only genuine medical insurance for this country lies in making the benefits of science available to all practitioners and to all patients. It is a large order'. The Foundation states that 'wherever fundamental research exists, no doubt would be expressed that medicine—meaning medical research, medical education, medical practice—is of course rooted in biology; or that the development of biological and medical research is increasingly influenced by the contributions of chemistry and physics (and atomic energy), [and] mathematics. This truth is as yet, however, only dimly reflected in the structure of medical education or in the point of view of medical practice'.

The report overlooks, however, certain obvious difficulties. It is clearly impossible to add systematic training in all the basic sciences to an already extensive course of medical education. The grafting of adequate scientific knowledge and of a scientific attitude onto the art of medical practice (which should not itself be lost altogether) presents a serious problem to medical educators; but it is a problem of which most are acutely aware. As stated above, the past 50 years have seen already a revolution in the attitude of the medical profession to the basic sciences, and there is no doubt that the process will continue.

This change in outlook of the public as well as of the medical profession has led in Great Britain to the enlightened application of public funds to medical research through the Medical Research Council and the University Grants Committee, as well as to the support given by great private endowments and organized public appeals to the charitable. All of these have been creations of the past half century. They have enabled the country greatly to expand its contribution to the advance of medical science. It is worth noting, however, that in Great Britain today the annual defence budget is about £1,500 million, and the budget for training and research in the physical sciences (Department of Scientific and Industrial Research, universities and technical colleges) is about £20 million.

The annual budget of the National Health Service for England, Wales and Scotland is about £500 million. The Medical Research Council and the basic research departments under the Ministry of Health receive less than £2 million. It is difficult to assess the proportion of the £25 million quinquennial grant to the universities which is used to support medical research, but it seems that the total government expenditure on medical research is less than £5 million, i.e. less than 1 per cent of the budget of the National Health Service. The contribution of private firms and endowments to medical research represents under £1 million a year.

The situation in the United States is not very different, as Professor W. M. Stanley has recently pointed out.[1] In that country $50 thousand million a year is spent on defence. The annual budget for research and development is about $4 thousand million, of which only about 5 per cent, or $200 million, goes to medical research in its broadest terms. But only about $80 million of this goes to support medical research in the universities, where (as the American Foundation Report emphasizes) most of the basic research is done. This is supported about equally by the Federal Government and by endowments of the universities and foundations. Thus the Federal Government contributes to medical research little more than one-tenth of 1 per cent of what is spent for defence against an external enemy. We ought—as Professor Stanley points out—to consider whether we can afford to spend so little for defence against disease. Professor Stanley argues strongly the case for unlimited support, with no strings attached, for persons with 'ideas' rather than for projects. No large number of people is involved; there are probably no more than 2,000 senior investigators in basic medical research in the U.S.A. and some 750 in Great Britain. Surely a reasonable proportion of these could be given the kind of support for research that is needed. Professor Stanley concludes that 'unrestricted support of our men and women with ideas would scarcely be noticeable in our economy and would bring incalculable benefits in health to millions who would otherwise suffer from disease'.

The American Foundation's report is not concerned with the past achievements of medical research and its social consequences. But any complacency about the present position should be dispelled by glancing at the second volume of the report, which lists and discusses selected clinical problems which are unsolved or only partially solved. These include cancer, infertility, arteriosclerosis, hypertension, the rheumatic syndromes, tuberculosis, virus diseases, alcoholism and schizophrenia; and the list could, of course, be greatly extended.

Clearly, much remains to be done. But application of the fruits of medical research during the first half of this century, and the concomitant improvement in the standard of living of the great majority of Western Europeans have already had striking results which appear in the reports of medical statisticians. Thus, the Registrar-General's Annual Report for 1898 tells us that in a population of about 31.5 millions in England and Wales, there occurred 552,141 deaths, of which 86,755 were attributed to 'zymotic' diseases—i.e. infections like influenza, dysentery, puerperal fever, etc. Fifty years later, in 1948, the population had increased by 12 millions, but the number of deaths was actually smaller by 82,243, giving a crude death rate

1. *Science*, Vol. 156, No. 3,192, 1956.

of 10.8 per 1,000 compared with 17.6. The group of diseases previously called 'zymotic' produced only 7,490 deaths in 1948, and their contribution to the total death rate fell from 2.76 per 1,000 to 0.17, or one-sixteenth of its value 50 years before.

Crude death rates ceased to be reliable indices of the improvement in health of the peoples of Western Europe since the first world war, when the cumulative effect of falling births and declining death rates among young people began to produce a rapid rise in the proportion of elderly people in the population. In England and Wales in 1901 the number of persons aged 65 and over in each 1,000 was 47 and in 1921 it was 60, but by 1942 it had increased to 105; and since the old necessarily die at a much greater rate than the young, this has had the effect of keeping the crude death rate at all ages almost constant at about 12.2, notwithstanding a progressive fall in death rates at every age. The rate of mortality in the first year of life per 1,000 live births—which is a good index of progress in standards of hygiene and medical care in any country—is now less than one-fifth of what it was in 1900. According to the death rates at the turn of the century, 4 out of every 10 girls and 1 out of 3 boys could expect to live to 65. The prospects are now very different, for more than 7 girls and 6 boys out of every 10 being born can expect to reach 65. Indeed, more than half the girls now born may expect to attain the age of 75.

Similar changes have been recorded in most Western European countries and in the United States, in all of which the life expectancy at birth stands at about 70 years. This process of 'aging' of the population presents serious social problems. It must lead to reorganization of labour resources so as to make the most efficient use of old people; and the provision of adequate housing and pensions for the aged adds greatly to the already immense burdens carried by the welfare state.

The impact of medical science on the populations of underdeveloped countries has been quite as spectacular. Wherever reasonably reliable statistics are available the trend that emerges is the same. Ceylon probably has the most comprehensive system of disease and death registration in all Asia, so that the mortality figures can be compared with those of Western European countries. Between 1946 and 1949 the crude death rate in Ceylon dropped suddenly from 22 per 1,000—a level typical of Asian or backward countries—to 12 per 1,000—one comparable with that in Western European countries. This can be attributed mainly to the widespread use of D.D.T. as a control measure for mosquitoes and other insect vectors of disease. Malaria has been nearly eradicated and there has been a large reduction in infant mortality and maternal mortality. But the birth rate in Ceylon has not even begun to drop, so that the population is growing at the rate of 2.7 per cent per annum—about twice the highest rate ever experienced in Britain.

The malaria eradication campaign in Mauritius resulted in a fall in the death rate from all causes from 27 to 14 per 1,000 in two years (1948 to 1950). In the same two years the infant mortality per 1,000 live births fell from 150 to 76, but there was a sharp rise in the birth rate to the high figure of 51 per 1,000. It will be appreciated that a serious problem of over-population is likely to arise in the island in the not too distant future. But here, as elsewhere, administrative officials are reluctant to encourage birth control. The Colonial Office is shy even of the mention of population control which, it is felt, might be construed as an attempt on their part to use it as a weapon against other races.

These examples reflect the situation in many underdeveloped countries. This is also beginning to appear in the vital statistics from these countries. In India, for example, the life expectancy at birth has risen within three decades from 20 to 32 years. The imminent danger of over-population in many parts of the world has been emphasized by several observers since the close of the second world war: it is a very real one. In 1949 the United Nations convened a conference on world resources at Lake Success; at the same time arrangements were initiated for holding a conference on world population. This was eventually held in Rome in 1954; but in the five intervening years the world population had increased by more than 130 million. We are now faced by certain stark facts. The total population of the world has been increasing relentlessly since records first became available. It is now more than 2.5 thousand million; and the annual rate of increase, at present some 34 million people a year, is also increasing.

Population growth passes through a series of stages. In the first stage both the birth rate and the death rate are high and the population increases only slowly. Most European populations were still in this stage a century ago, and many African populations are in it today. In the second stage the death rate falls sharply but the birth rate remains high, so that the population expands more or less explosively. Many Asian populations are now in this stage. In the third stage the birth rate also falls sharply, so that the increase of population is slowed.

Surely it is the eventual objective of medical science to hasten the onset of the third stage: to stabilize birth rates and death rates at an increasingly low figure, so that the populations of all countries are healthy, well-fed and long-lived. And to achieve this end, surely it is obvious that the first requirement is a simple, cheap and reliable method of birth control. The official and private attitudes to family limitation cannot remain unchanged: Japan and India have already adopted officially the policy of population control. In the face of a need like this, it is curious that birth control is not even mentioned in the 1,505 pages of the American Foundation's report on Medical Research, although 57 pages are given to a discussion of infertility. This situation is the more surprising in view of the claim made in the fore-

word: 'In all of these studies, our objective has been to set up defenses against the lack of fact and the weight of particular propaganda that inhibit clear thinking on many important questions.'

A. C. ALLISON

Dr. Allison is Dr. Lee's Reader in Anatomy and Student of Christ Church, Oxford. His main field of interest is in biochemical genetics. He has worked in the U.S.A. and in several African territories.

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